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TIME SERIES ANALYSIS OF ANALOG DATA BY ANALOG-TO-DIGITAL AND DIGITAL DATA PROCESSING METHODS AT THE NAVAL POSTGRADUATE SCHOOL

By

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THESIS

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BY ANALOG-TO-DIGITAL
AND DIGITAL DATA PROCESSING METHODS
AT THE NAVAL POSTGRADUATE SCHOOL

by

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March 1971

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ABSTRACT

Time series data consisting of temperature and velocity fluctuations recorded two to four meters above a tidal mud flat were processed to produce power spectra. The analog data were first processed through an Analog-to-Digital computer consisting of a Hybrid Computer System (XDS 9300/Ci 5000). The resulting tapes, in octal representation, were converted to hexadecimal representation for further processing on a 768k byte storage digital computer (IBM 360/67). A series of three digital programs were used to compute and plot Fourier coefficients in spectral form. Digital data processing procedure using magnetic tape on the two computer systems is explained in detail and specific examples of programs and control card decks are given. Significant noise levels were encountered in the Hybrid Computer System (ADC) which must be eliminated in future studies.

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I. INTRODUCTION

A. BACKGROUND

Continuous improvement in the design, speed of operation and storage capacity of digital computers allows an ever increasing flexibility in data handling capabilities and procedures. In addition, there has been a parallel development in the mathematical techniques of treating various stochastic processes. One of these developments, the fast-Fourier transform (FFT) formulated by Cooley and Tukey (1965), will be discussed and applied extensively in this thesis. The coupling of improved computer capability and improved analysis techniques has led to the ability to process large sections of data that would previously have been considered prohibitive. The object now becomes how to do this efficiently. This thesis describes a method of how to efficiently handle one kind of data, geophysical turbulence data, by these recently developed tools.

Geophysical turbulence data is frequently recorded on analog tape. Such data must be digitized (via an analog-to-digital converter; ADC) in order to take advantage of digital techniques. The goal of this thesis is to formulate, under one cover, a complete description for analyzing time series data on facilities which are presently available at the Naval Postgraduate School (NPS). Problem areas and proposed solutions to these problems are discussed.

The FFT is a highly efficient procedure for computing the discrete Fourier transform of time series data. This algorithm takes advantage of the fact that the discrete Fourier transform can be carried out iteratively, which yields large savings in computation time. If a time series consists of $N = 2^n$ samples, then $2nN = 2N \log_2 N$ arithmetic operations will be required to evaluate all N coefficients of the discrete Fourier transform. Conventional procedures (non-FFT) require about N^2 computations, considerably more steps for a computer when N is large. A time series of 8192 ($N = 2^{13}$) samples require approximately 214,992 (2nN) arithmetic operations by FFT and 67,109,864 (N^2) by conventional means. In terms of computer time, the economical advantages of the FFT are self-evident. It has been reported (Cochran, et. al., 1967) that the above FFT calculations require five seconds on an IBM 7094 computer. Conventional procedures take about half an hour.

The Naval Postgraduate School has two sophisticated computer systems. The Hybrid System is composed of an analog computer (COMCOR Ci 5000), containing 50 amplifiers, interfaced with a digital computer (XDS 9300) with 32K bytes of core space. The other and larger of the two systems is the IBM 360/67 with a core space of 762K bytes. These computer systems are physically and electrically separated, (i.e., different buildings). Each system is operated and maintained by separate administrations. The Hybrid computer, located in the Electrical Engineering Computer Laboratory, is operated under the Electrical

Engineering Department. The IBM system is located in the Computer Center, which is operated and maintained by the Computer Center Staff. The two independent systems provide services for different disciplines and consequently different forms of data are used. The Hybrid system operates by use of octal language and the IBM system operates by use of hexadecimal language. The two languages are not compatible without conversion. The unfortunate fact is that time series data analysis requires the use of both systems. The Hybrid system must be used for analog-to-digital conversion and the IBM system must be used for analysis because of its large memory size.

Thus, two excellent computer systems are available but time series analysis must involve both systems; and due to the separate physical locations, different administrations, and incompatible languages, several difficulties are encountered in performing time series analysis.

The initial effort to facilitate processing of time series data at NPS was made by Wilson, Boston and Denner (1969). A series of three digital programs were made available to NPS through the Institute of Oceanography at the University of British Columbia, Vancouver, B.C. These programs were converted for use on the NPS IBM 360/67 computer system in February 1969. These programs (UBCFTOR, UBCSCOR and UBCFCPLOT) are used to compute Fourier coefficients (via FFT) and plot the coefficients in spectral form. Numerous options are available in the plotting portion of the programs. They will be discussed in detail later.

B. APPLICATIONS OF SPECTRAL ANALYSIS

1. Turbulence

Turbulence is usually considered to be erratic changes in direction and speed of fluid flow at a point.

a. Geophysics

Turbulence is found in some form in all studies of geophysics. Understanding the turbulent nature of these geophysical processes yields some insight into the origin of the processes and propagation of their signals. An example is seismic studies relating to earthquake analysis and prediction. Spectral representation yields order to the randomness of the process and empirical information may be thus inferred. Research into the composition of the earth's mantle is based mainly on spectral analysis of sonic signals propagating through the mantle and crust.

b. Engineering

Aeronautical engineering studies are frequently carried out in wind tunnels. The fluctuations of the fluid flow in the wind tunnel are examined via spectral analysis. Structural vibrations are examined by spectral means. Spectral analysis is used to determine the influence of noise on electrical guidance systems. Ship hull vibration caused by wave action is examined by spectral analysis. Fluctuations of structures and fluid flow in the engineering disciplines are studied by spectral analysis techniques.

2. Acoustics

Propagation loss, due to microstructure, of sonic signals through a fluid medium can be analyzed by spectral means. An example of a time series examined by spectral means with Naval application is helicopter hover noise transmitted to underwater sonar transducers while performing inflight sonar operations. Human voice analysis, underwater and in air, is another time series frequently studied by spectral analysis.

3. Environmental Processes

a. Meteorology

Meteorology is concerned with the fluctuations of atmospheric parameters like temperature, wind speed, wind direction, humidity, location of isolines, and many others. All these fluctuations can be studied by spectral analysis. Particular importance is given to small scale processes as they relate to heat transfer to and from the atmosphere. The small scale fluctuations are normally examined by spectral means.

b. Oceanography

Many ocean processes are time series in nature and lend themselves well to spectral analysis. A few are: surface waves, internal waves, tidal cycles, sediment transport, oceanic currents, and small scale processes. In oceanography, as in meteorology, small scale processes (ocean microstructure, air-sea interaction) are frequently studied by spectral analysis. The spectral representation is more easily

understood as frequency components are identified. In this way, momentum and momentum flux transfer (and appropriate constants) are examined in an attempt to determine the exact relation between wind, velocity, waves, and temperature of the atmosphere and ocean.

II. CONSIDERATIONS IN TIME SERIES DATA COLLECTION AND ANALYSIS

The data used in exploring the analysis phase of the data processing procedure were differentiated and undifferentiated temperature and velocity fluctuations recorded four meters above a tidal mud flat. These contained frequencies that ranged from D.C. to 1000 Hertz for the undifferentiated signals and approximately 1 Hertz to 2000 Hertz for the differentiated signals. The signals were filtered at 10 kHz when originally recorded (Boston, 1970).

A. PRIMARY DATA

Often, time series studies involve the collection of large amounts of data which are recorded on magnetic tape. Such data may be processed by analog means, or digitized, then processed by digital machines. Each method has its advantages and disadvantages. But for the purposes of this study, the digital procedure was the only one of interest. In the digital procedure, a number of intermediary stages are involved before final results are obtained. Each stage offers opportunities for errors and loss of signal purity. Since each stage presents unique problems, each will be discussed in turn.

1. Analog Signals

One such stage in the digital procedure is conditioning the raw signal to render it acceptable (optimum) to the Analog-to-Digital converter (ADC). The type and amount of conditioning is based upon the characteristics of the raw analog signal. Most frequently considered characteristics are noise level, D.C. level and signal level.

a. Noise Level

The noise level of the analog signal is partially dependent upon the signal collection technique as the collection system of necessity has noise ("System" noise such as "60 cycle" power supply noise and associated harmonics). Another type of noise is "ambient" noise (analog filters, pre-whiteners, etc.) which normally contaminates the higher frequencies mostly and may be aliased into lower frequencies. Aliasing is discussed more fully in a later section.

b. D.C. Level

An unavoidable D.C. level is frequently found in analog signals and is a function of collection technique as was system noise level. The D.C. level shows up in undifferentiated signals and usually must be eliminated. However, differentiated signals have no D.C. level as the differentiating function acts as a high pass filter. High pass filtering is frequently employed to deal with unwanted D.C. level.

c. Signal Level

The analog signal must be large enough to take advantage of the full dynamic range of the ADC. In order to do this, amplification

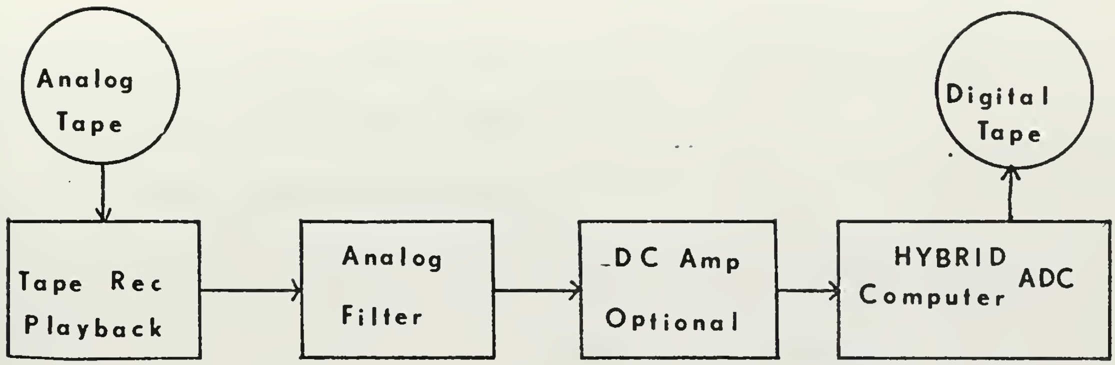
of the signal is required. As seen in figure 1, the raw analog signal must pass through the analog low pass filter to eliminate high frequency noise, and through the D.C. amplifier to take advantage of the ADC dynamic range before entering the ADC. These two devices provide additional sources of noise for the analog signal. Therefore, the signal to the ADC is not as "pure" entering the ADC as when recorded during the data collection procedure.

d. Spurious Signals

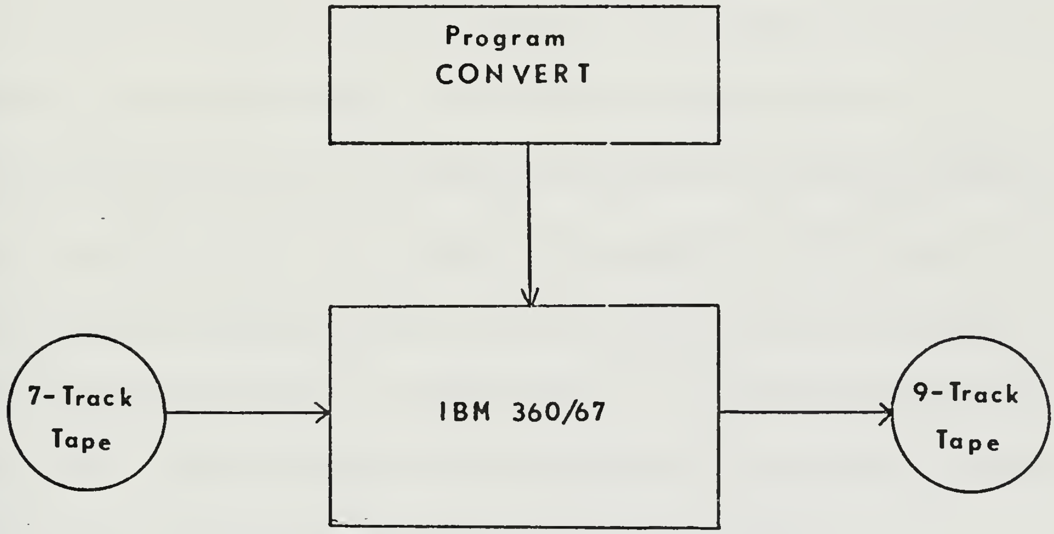
In addition to the above factors, further problems in the form of spurious signals may be encountered if laboratory equipment is not properly grounded or cables and connectors are not properly shielded. Spurious signals are extremely difficult to isolate once encountered as they are frequently intermittent, and of various characteristics which makes the spurious signals difficult to identify from spectrum to spectrum.

2. Signal Level of Actual Analog Data

The primary analog data had an amplitude of about $\pm$ 1 volt. The Hybrid computer (XDS 9300/Ci 5000) used for Analog-to-Digital conversion is able to digitize signals of $\pm$ 100 volts amplitude. This condition requires amplification of the analog signal to take advantage of the full dynamic range of the Analog-to-Digital converter (ADC). Since the ultimate outputs were power spectra, the amplification factor was of no consequence other than to utilize the best dynamic range of the ADC. Situations exist whereby the absolute values of the amplitudes would be



a) Analog-To-Digital Conversion



b) Seven Track to Nine Track Conversion

Figure 1 Block Diagram of Analysis Procedures

important. In such a case, the digital program to compute the Fourier Coefficients (FTOR) was able to account for the amplification factor by a simple control card entry (calibration).

3. <u>High Frequency Analog Signals</u>

Extremely high wave number data (10 kHz and higher) was not utilized in this study, but useful information concerning its Analog-to-Digital conversion is here included. In using the Hybrid Computer System at the Naval Postgraduate School for an ADC, the limiting factor in digitizing high wave number data at a high sampling ratio was the speed with which the tape drive units responded to the "write" command of the digital computer (XDS 9300) of the Hybrid Computer System. The realistic maximum rate of sampling was discovered to be 4000 samples per second per channel. Any faster rate resulted in a "rate error" and the abortion of digitizing effort for that portion of data. This topic will be discussed further in a later section. The solution to this high wave number data problem is to slow the playback tape speed and sample the signal at a rate proportional to the slow-down time.

EXAMPLE: "Real Time" tape speed = 60 inches per second (ips).

Desired sampling rate = 10 kHz

Playback speed = 15 ips (60 ips x 1/4=).

Hence, sampling rate = 2.5 kHz (10 kHz x 1/4=).

Experience showed 2500 samples per second to be a reasonable rate for the tape drive machines used.

B. RECORD LENGTH CONSIDERATIONS

In this study, "record" was taken to mean the amount (in seconds) of raw analog signal on one track (14 tracks total) of the analog magnetic tape. A "block" was a specific number (2048 for two channels) of digital samples of analog signals grouped together physically on the digital 9-track tape. Seven-track tape specifies octal language which is used by the XDS 9300.* A "file" is a series of "blocks", the end of which is denoted by an "end of file" mark on the digital magnetic tape. The "block" is made up of "words" (samples) composed of "bytes". A "byte" is a group of ones and zeros which form the binary language used in the majority of digital computers.

In terms of digital tapes, "record" was taken to mean the number of blocks in one file on a digital tape. A digital tape can hold many files depending on the lengths of the files (length of the record). The interchangeability of the word "file" and "record" as a measure of amount of data, came into being because a "record" of analog signal was usually digitized onto a single "file" on a tape. The number of blocks contained in a file was the only true measure of digital tape length. The digital "length of record" was important to know in digital data processing. It was found that 1368 blocks of 7-track tape (Hybrid Computer output)

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* Xerox Data Systems (XDS) is the present name of Scientific Data Systems (SDS). XDS 9300 Digital Computer is better known as SDS 9300.

would completely fill a 9-track tape (IBM 360/67 Computer System) with complex Fourier coefficients. If more data than 1368 blocks were processed, significant changes in the IBM 360/67 Computer System control cards had to be made and frequently, additional computer runs would have to accompany the control card changes. Thus, the digital "length of record" (number of data blocks) is important to know in digital processing and the number of blocks in a file is the only way to judge the amount of data on a digital tape and the amount of tape left for further use in storing data.

The limiting factor of record length, in the analog sense, is imposed by the lowest frequency of interest. The shorter the record, the fewer cycles of a specific frequency (f_1) will be contained in that record and hence, the less reliable the spectral estimate of the frequency (f_1) will be. The reliability of spectral estimates is found by examining the degrees of freedom (D. F.) associated with a bandwidth,

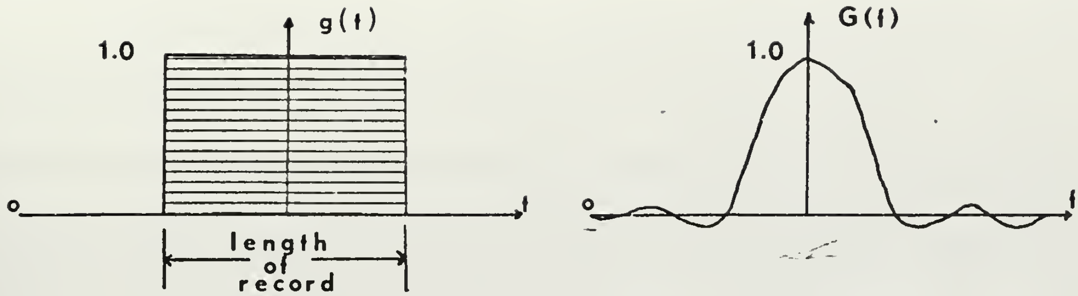
$$\text{D. F.} = 2T \times \text{bandwidth}$$

where T is the period (1/f) of one cycle and degrees of freedom is twice the number of observations that appear within the bandwidth. Bandwidth can be expressed as a function of frequency (i.e., $f/\sqrt{2}$ for a half-octave filter bandwidth). A table of D. F. versus 80% (for example) confidence limits can be consulted to find the minimum spectral estimates required to assure 80% confidence limits in the low frequency spectral estimates (see Blackman and Tukey, 1959).

1. Finite Record Length

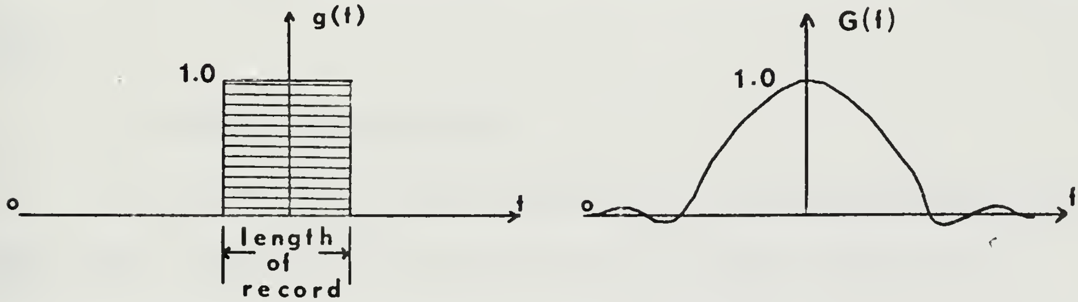
The central problem of proper record length is optimizing the length of record. The only absolutely true representation of a geophysical process is an infinite time series record. It is, of course, not possible to obtain such a record. A very long record may well describe a process within the accuracy desired. Frequently a very long record may be longer than necessary to adequately describe a stationary (i.e., homogeneous air turbulence) process. If a record is longer than necessary, it is uneconomical to process because of computer time and experimental time. However, no harm is done by obtaining long analog data records. Good raw analog data is difficult to obtain and too much raw data is an unusual situation. The digital records may always be adjusted to a desired length, but the only remedy for insufficient raw data is recreating the data collection phase, often a costly and time consuming procedure.

A consideration in optimizing the length of a record is the relation between length of record (T) and the shape of the convolved wave forms (Fourier transform) for that particular length of record. Convolving a record with a rectangle function such as figure 2a results in a "blurred" spectrum of the original signal as each element is expanded like figure 2b, which is the transform of the block function, figure 2a. Since the longer the record length (T), the less will be the spread of the transform over the frequency domain and the truer will be the spectrum (see figure 2c and figure 2d). A limiting case is the transform of a sine (or cosine)



a) Rectangle Function

b) Transform of a)



c) Rectangle Function

d) Transform of c)

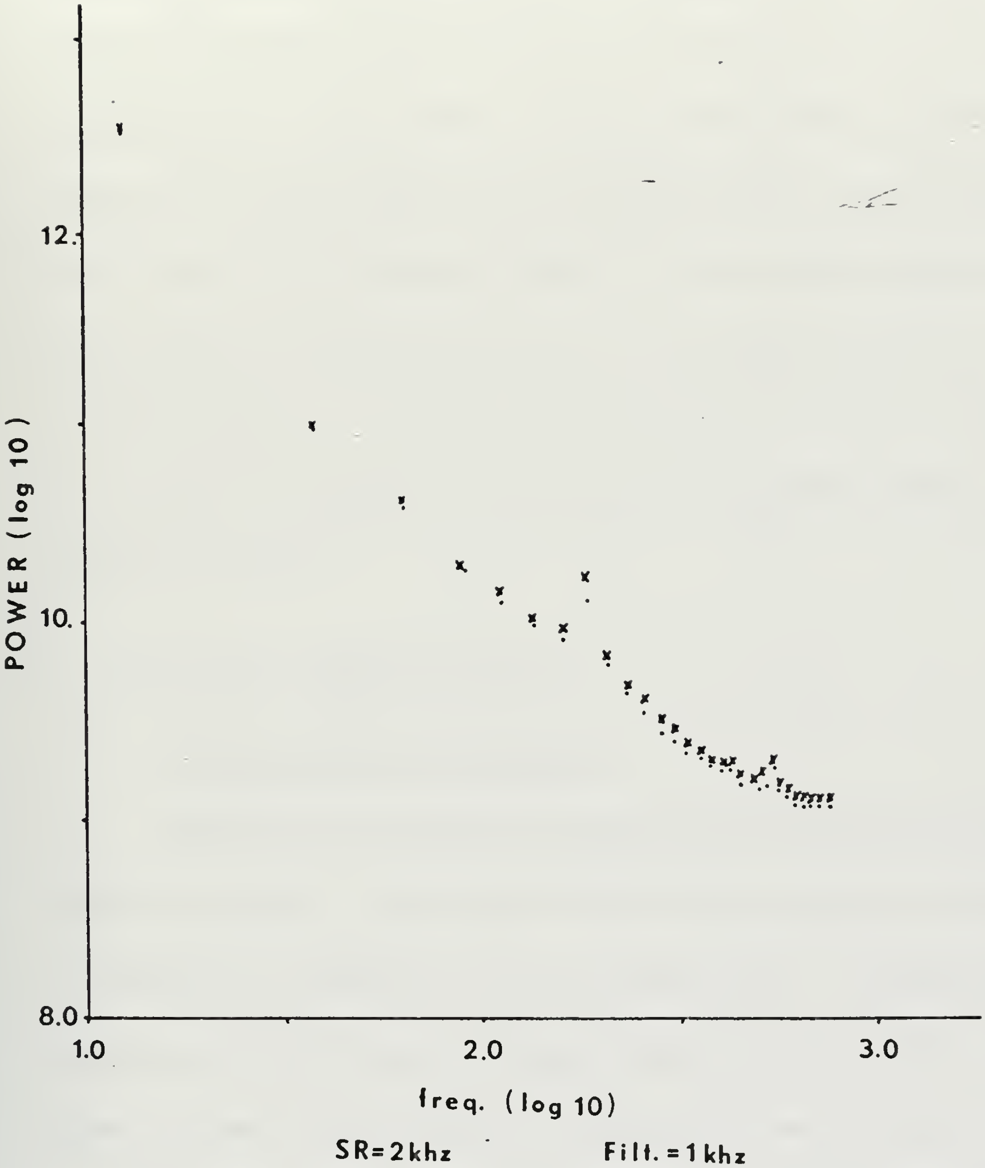
Figure 2 Fourier Transforms of Rectangle Functions

function which results in a Dirac delta function in the frequency domain. The Dirac delta function is an exact spectrum of the sine waveform and consists of a "spike" on the frequency axis of a plot. However, being unable to obtain an exact spectrum for a block function, an intermediate position must be taken. There will be some length of record where the difference between the true spectrum and convolved spectrum is negligible. This length of record is the optimum length of record from a practical and processing point of view.

This value of optimum length of record was not found exactly, but it was discovered that increasing analog signal record lengths from 140 seconds to 360 seconds had virtually no effect on the shape of the spectra (figure 3).

2. Computing Time Required

A consideration of record length which was examined during the data analysis, was to estimate digital computer (IBM 360/67) time required to process various lengths of data records. A complete survey of required time for various record lengths was not carried out, however, it was found that computing Fourier coefficients by use of the FTOR program required the most computing time of the programs used. A convenient unit of measure common to all data studied was block length. A block length of 2048 (2^{11}) words was used throughout the study. For the FTOR program, about 20.5 seconds was consumed in compiling the program. Thereafter, about 1.07 seconds per block was used for computing coefficients. The remaining three programs (CONVERT,



x— Spectrum of Six Minutes of Data

·— Spectrum of Two Minutes of Data

Figure 3 Comparison of Velocity Spectra for Two Lengths of Record

SCOR, FC PLOT) required less than 10 minutes per volume (about 1368 blocks of 2048 words fill a tape reel) of digital tape. The programs SCOR and FC PLOT varied in total time depending on the type of plots specified in the control cards. It was concluded that requesting 10 minutes of computer time on the "JOB REQUEST" card for CONVERT, SCOR, and FC PLOT allowed adequate time for jobs of any size and did not increase the "return time" from the Computer Center. All jobs requiring magnetic tapes were given low priorities in any event and specifying the requested time as less than 10 minutes did not raise the priority of the job.

C. ANALYSIS CONSIDERATIONS

1. Sampling Rate and Filtering

Selection of sampling rate was a critical point in the Analog-to-Digital conversion. Knowledge of the maximum frequency of the data is essential in selecting the proper sampling rate. Sampling rate is usually selected as twice the highest frequencies of interest. Frequencies above 1000 and 2000 hertz contained mostly "system" noise.

The system noise on the analog signals tape was a problem (i.e., aliasing) without proper filtering. Aliasing is a well known spectral analysis problem and is dependent upon the value of the folding (Nyquist) frequency (figure 4). The folding frequency is, in turn, a function of sampling rate as it occurs at one-half the sampling rate. All energy above the folding frequency is folded back into the spectrum and the

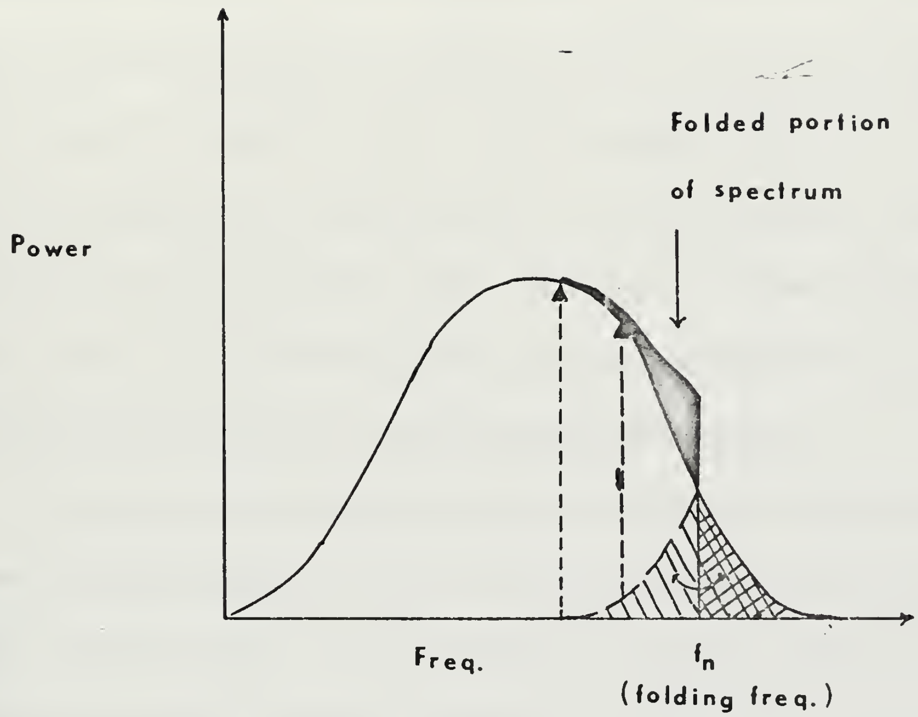


Figure 4 Example of Aliased Spectrum. This is not Actual Data.

"true" spectrum becomes contaminated with "aliased" noise, folded back from higher frequencies. Because of aliasing, filtering of data was essential to eliminate all significant energy above the folding (Nyquist) frequency to obtain a "true" spectrum (i.e., free of aliased noise). Sharp cut-off analog filters (48 db per octave) were used to minimize the amount of "folded" energy. A disadvantage of sharp cut-off filters is their propensity for "phase shifting". If a correlation or higher order moments study is undertaken, phase shifting due to sharp filtering must be considered. This study, however, was not concerned with correlation or higher order moments, so phase shifting was ignored.

In summary, aliasing (a function of sampling rate) essentially determines the "high frequency" limit. This limit, combined with the previous "low frequency" limit, set by the degrees of freedom (related to desired confidence limits), specifies the full bandwidth of the spectrum of interest.

2. Resolution and Stability of Data

Once Fourier Coefficients were computed (via the FTOR program) and spectra were desired, the question of resolution of data arose. Increased resolution yields more detail about a spectrum. This would imply few spectral estimates in a very narrow bandwidth of frequencies. This situation would, at first, appear to be good but, in fact, this increased resolution yields less accurate spectra. Individual spectral estimates could not be plotted. Instead, bandwidths containing spectral estimates were averaged, mean and variance computed, and plotted. Thus, the

average of only a few spectral estimates represented the apparent estimate of a particular bandwidth, when in fact a wide difference in spectral values (Fourier Coefficients) of individual frequency components in that bandwidth could exist. With a narrow bandwidth over which to average, wide variation in the slope of the full spectrum was seen. Wider bandwidths (greater than 32 hertz for a folding frequency of 1 kilohertz) were necessary to yield a reasonably smooth spectrum up to the Nyquist frequency. Also, the plotting programs (SCOR and FC PLOT) were constrained to average over a maximum of 32 bandwidths. Thus the selected bandwidth was normally set to show best the area or feature of interest of each spectrum.

An interesting way to look at resolution as related to bandwidth is by analogy. Consider a multi-frequency signal and a plot of its Fourier coefficients' amplitude (a_n and b_n of the Fourier series) versus n (which is related to frequency by $n = fT$). As the number of Fourier coefficients (F. C.) per frequency increases (n increases), it becomes more difficult to distinguish individual F. C. amplitudes. To circumvent the problem, groups (of approximately equal size, for example) of F. C. amplitudes are considered. This is similar to replacing a group of sticks in the ground by a single large post whose height is the average height of the sticks. This analogy conveys the concept of amplitude density and energy level per bandwidth. The resolution of the many sticks is sacrificed to yield a better "mean" value of the bandwidth as represented by the single post of averaged height.

Stability of data decreases as resolution of data increases. Stability of the data, as viewed in spectral form, relates to the confidence limits desired of the spectral representations. By finding the degrees of freedom from a chi-square table, the minimum number of frequency components per bandwidth is found for a specific confidence limit. This information provides a guide for selecting a proper low frequency limit for the bandwidth of the spectra. A stability investigation was not undertaken in this thesis but future studies will be extremely interested in this aspect of the spectral representations.

3. Noise

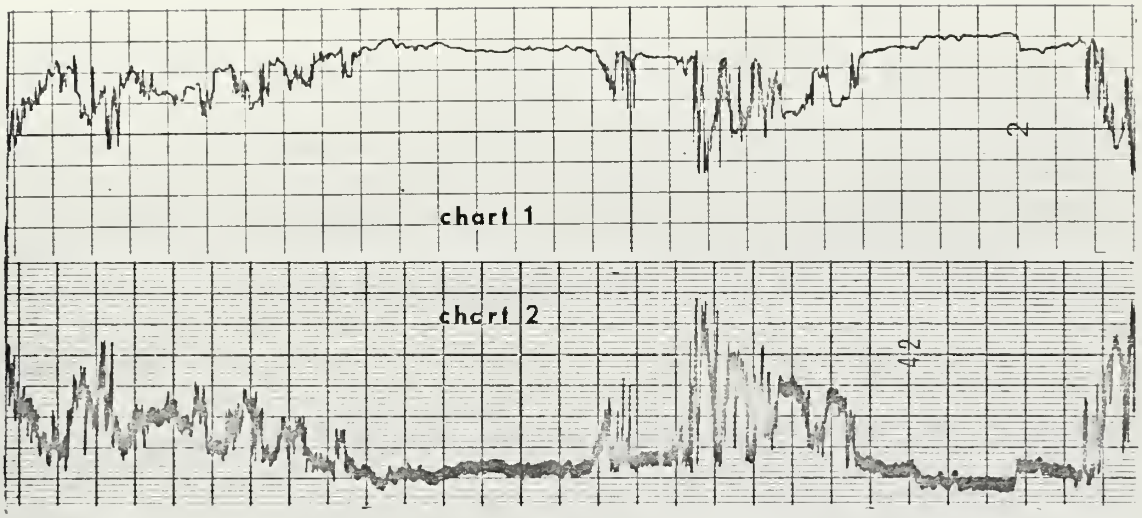
System noise is usually not very important at frequencies below 10 hertz. This fact is fortunate in air-sea interaction as this range is where the majority of fluxes occur. However, for wind tunnel and high wave number geophysical turbulence, noise is often the limiting factor. Hence, great care in the design, construction and procedure of experiments is essential. Frequently electronic techniques must be developed to circumvent the noise problem. An example is differentiating (pre-whitening) the analog signal to increase the signal-to-noise ratio at high frequencies.

System noise is a difficult problem in data collection and even more so when additional noise is introduced in the various analysis phases. The analog data had a high signal-to-noise ratio and little or no noise problems were anticipated in the data analysis phase. This was not the case. It was discovered that noise was introduced into the analog

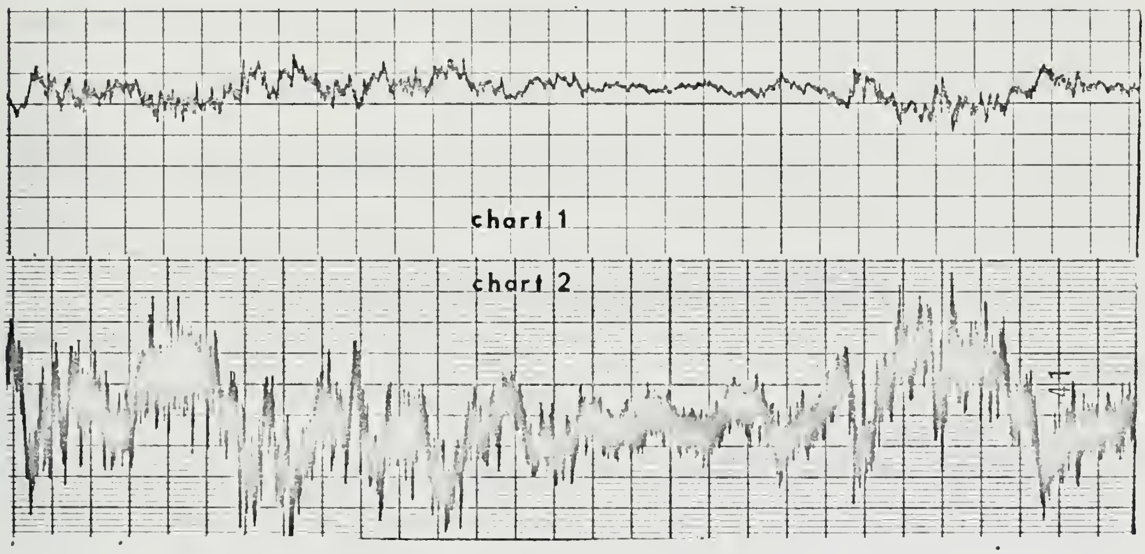
signal by the removable analog patchboard on the Ci 5000 analog computer of the Hybrid Computer System. This fact was noted by attaching one of two leads (from the same analog tape channel) from the tape playback device to a strip chart recorder via the analog patchboard without any amplification. The noise picked up in the patchboard is very noticeable (relative to the signal, figure 5). To insure that both strip chart recorders gave the same response, both leads were attached to the recorders directly from the analog tape playback device. Identical recordings of the signal were made, thus eliminating the strip chart recorders as a source of noise in the noise analysis of the patchboards.

To eliminate the noise introduced by the patchboard it would be necessary for future studies to electrically enter the analog computer after the removable patchboard which would bypass the source of noise. A good low-noise, external amplifier would then be necessary to ensure the input signal was large enough to use the best dynamic range of the Hybrid Computer. Also, it would be advisable to undertake a series of steps to determine exactly the source and magnitude of noise in the ADC.

The use of known waveforms as input analog signals would be useful in determining the source and magnitude of noise in the ADC. A sine wave analog signal would yield a line (Dirac delta function) spectrum and show noise picked up in the ADC. The effect of filtering could be checked in this way. This procedure was used in this study but the results were inconclusive for specifying sources of noise. The effect



a) Air Velocity Data - (Top) Without ADC Patchboard Noise, (Bottom) Identical Signal With Patchboard Noise.



b) Air Temperature - (Top) Without ADC Patchboard Noise, (Bottom) Identical Signal With Patchboard Noise.

Figure 5 ADC Patchboard Noise Comparison

of filters was confirmed in this way (one of many ways used). It is suggested that a square wave analog signal be used as an input to the ADC as the resulting spectrum is a well-known shape (Fourier transform of a square wave, figure 2 b and 2d. In this way, the accuracy of the ADC may be checked over a frequency range wider than a single frequency sine wave.

The problem of noise was possibly not confined to the ADC. It was suspected that other steps in the digital processing (converting to 9-track, principally) caused noise, but unfortunately these sources were not pinpointed. Due to the nature of spectral presentations (log-log plots), it is possible to "hide" noise in the spectra and only extensive manipulation of spectral presentations (bandwidth, number of spectral estimates per bandwidth, expanded scales for plotting, etc.) can the noise be clearly identified and subsequently eliminated.

III. FACILITIES AND EQUIPMENT

A. HYBRID COMPUTER SYSTEM

The Hybrid Computer System is composed of an analog computer interfaced electrically with a digital computer. The system is located in the Electrical Engineering Computer Laboratory on the fifth floor of Spanagel Hall.

1. The Analog Computer (Ci 5000)

The COMCOR Ci 5000 analog computer was operated on a

self-service basis. The computer center staff (three men total) was available to assist in the set-up and operation of the computer. The analog computer has two removable patchboards which are the heart of the system. The "logic" patchboard (the smaller of the two) was utilized in this study to set the sampling rate in the analog computer. The sampling rate may be changed by altering a counter-like number display located below and to the left (facing the patchboard) of the logic patchboard. The counter operates a voltage divider which is electrically connected to a resistance input on the logic patchboard. The resistance value is divided by the counter setting plus one to give the sampling rate desired. The "analog" patchboard (larger one) was used to apply the proper amplification factor to the input signal and connect the input signal to the built-in oscilloscope which is able to display up to four signals (analog channels) at once. All signal inputs enter the analog computer via the "analog" patchboard. The analog computer has an internal white-noise generator for "pre-whitening" signals if so desired. A simple patchboard circuit was required and the computer center staff assembled the circuit which was placed on a reserved (by number) analog and logic patchboard for subsequent use. The analog computer has a keyboard console to control which mode of operation is desired. The mode was set during the energizing phase of the computer operation. The mode for ADC was always "keyboard". The "keyboard" mode was used because the logic patchboard was patched to allow for manual

control of the starting and stopping of the digitizing operation. More specific information on the computer operation may be found in Section IV.

2. The Digital Computer (XDS 9300)

The digital computer interfaced with the analog computer is a Xerox Data Systems (XDS 9300) model. The core storage is about 32,000 bytes. Two tape drive units are available as input or output devices. One printer is available for program listings, outputs, and printer plots. A card reader is associated with the digital computer as the avenue of input for compiling programs. A teletype unit is located adjacent to the central console of the computer for parameter inputs and instructions to the digital computer program. The control console of the XDS 9300 contains control switches which have many uses, one of which is to control the compiling of a program. Use of these switches for program compiling are discussed in Section IV which is concerned with energizing the Hybrid Computer System. Due to the limited core storage (32K bytes) of the XDS 9300, the IBM 360/67 was used for digital data processing.

B. THE DIGITAL COMPUTER SYSTEM (IBM 360/67)

This computer system is located on the ground floor of Ingersoll Hall in the Computer Center. The staff which operates the center is large (about 30 persons) and maintains a 24-hour operating schedule. Virtually all students at NPS utilize this system at some time. The

system is also taxed with the chore of housekeeping functions of the school administration (i.e., payroll, library inventory, equipment inventory, etc.). The system is normally heavily used but the capacity of the system is large. The system consists of three memory boxes and two compilers for a total of 768,000 bytes of core storage. The system uses many languages but FORTRAN IV is the most commonly used language. Inputs can have the form of cards, magnetic tapes, or remote teletype communications via any of 20 remote units located throughout the various campus buildings. The outputs may have the form of printed listings, printed plots, magnetic tapes, punched cards, or ink diagrams drawn by the CALCOMP plotter. The system has three CALCOMP plotters, six tape drive units, two printers, and two card readers, one of which is directly available to users; whereby a user can "read in" a card deck directly to a computer buffer rather than allowing a staff member to do this. The self-service card reader ("Hot" Card Reader) is available only during specific hours of the day and night. This IBM system contains a full library of subroutines specifically designed for scientific use. Many of these subroutines are used in the CONVERT, FTOR, SCOR, and FC PLOT programs.

IV. ANALOG-TO-DIGITAL CONVERSION

A. EQUIPMENT OPERATION

1. Analog Tape Playback

The analog signal was originally recorded on one inch magnetic

tape. The tape contained 14 tracks of data and two edge tracks for voice recording. The tape playback was on a SANGAMO FM tape recorder, model 3562. Each channel of the analog tape to be digitized was connected to a KROHN-HITE model 3340 filter. The filter outputs were connected to the "analog" patchboard as inputs to the analog computer. The magnetic heads and tape rollers of the tape recorder were cleaned with isopropyl alcohol after prolonged use. The cleaning was to prevent the development of noise during tape playback.

The analog patchboard was wired to amplify each input (normally two channels for this study) by 50 to take advantage of the full dynamic range of the Hybrid Computer. As previously stated, the raw signal had an amplitude of approximately one volt and the Hybrid Computer has a dynamic range of $\pm$ 100 volts.

2. Patchboard Noise

The patchboards were found to be a source of noise and therefore a problem in the ADC. As described in Section II-C and seen in figure 5, the patchboard noise was considerable. It can only be assumed that amplifying the signal introduces even more noise than is evident in figure 5. The noise encountered in the analog computer patchboard must be eliminated or greatly reduced in future studies to ensure accurate ADC. One method of by-passing the patchboard is to have a low-noise, external amplifier and input the analog signal to a specially wired circuit, not to include the removable patchboard.

3. Tape Channels

Two channels of the analog tape were digitized at once in this study. This situation created a digital tape which consisted of blocks of data 2048 words in size (other sizes may be specified) and every other word in each block was a data sample from one of the channels. Each block of data contained 1024 words (data samples) of each channel. A maximum of six channels may be specified in the multichannel digitizing program. Block size may be enlarged to accommodate more channels but a maximum of 8192 words (2^{13}) can be processed in the Fourier coefficient computation program (FTOR). It was discovered that increasing the number of channels increased the complexity of the programmer's task. More areas for error were opened up by using more than two channels and a first attempt should include only one channel. For correlation studies, the tracks containing the data of interest must be digitized in channels and placed in the same block on the digitized tape. The only other reason for using multichannels would be to conserve magnetic tape and ultimately process more data in less computer runs. Further explanation of channel considerations may be found in Wilson, et. al. (1969).

4. Energizing the Hybrid Computer System

The procedure listed below was used to energize the Hybrid Computer System without extensive instruction by the computer center staff. An abbreviated version of the procedure is kept near the XDS 9300 console for easy reference.

a. Energizing the Digital Computer (XDS 9300)

Press the RESET button on the console and then the POWER button. Energize the teletype by turning the knurled knob (lower right side of keyboard) to ON.

b. De-energizing the Digital Computer (XDS 9300)

Turn off teletype (knurled knob) and depress IDLE button on XDS 9300 console panel. Ensure the teletype power is always OFF whenever the XDS 9300 power is turned OFF or ON.

c. Energizing the Ci 5000 (Analog Computer)

This step follows the above steps. Depress ON switch/indicator at lower left corner of display panel of Ci 5000. Depress KEY BOARD button on the mode selection keyboard which contains buff keys in an orange casing.

d. Energizing the Line Printer

Next, depress the POWER switch/indicator on the face of the printer. Approximately one minute later the lower half of the POWER button/light will light up to indicate the printer is energized. Then, depress READY switch/indicator. The READY switch/indicator must be OFF (dark) before manually advancing the printer paper.

e. Energizing the Card Reader

Next, place "BOOT" card ahead of the "Δ JOB" card in the multichannel digitizing program card deck and place deck in card reader's input hopper and place weight on the top of the deck. The "BOOT" and "Δ JOB" cards are standard control cards for the XDS 9300. Examples

are readily available in the computer facility. Place card deck face down with "12" edge (top) toward the outside. Depress POWER ON and START buttons. Ensure metal cover enclosing the center portion of the card reader is firmly in position or a safety interlock will de-energize the card reader.

f. Compiling the Program

Next, at the XDS 9300 console, with all sense switches off (six buttons on bottom left row), depress in this order: IDLE, RESET, RUN, CARDS. The digital computer will compile the program and upon completion of compiling will write via the teletype "END OF ASSEMBLY". The parameters associated with the digitizing program are then entered by typing them in, and asterisk and carriage return buttons are depressed. The Hybrid Computer System is ready to receive the options specified in the digitizing program.

g. Mounting Magnetic Tapes

The final procedure is to mount the magnetic tapes on the tape drives. The system has two tape drives and threading instructions are posted on the inside of the protective doors over the tape reels. Care must be taken to mount the "feed" reel straight (without any wobble) and firmly screw down the center post. It is extremely important that the tapes used in the ADC be <u>absolutely free of permanent errors</u> (<u>i.e.</u>, scratches, creases, tears, oily spots, loose oxide dust). Any tape error encountered in the writing phase of the ADC will result in the computer attempting to write over the tape error, again and again, until it

succeeds. If the next block of data is ready to be written (*i.e.*, the buffer is filled) and the previous data block has not been written on the tape yet, a conflict results in the computer. The phrase "RATE ERROR" will be subsequently typed out on the teletype. The only recourse is to put an END OF FILE on the tape and start digitizing over again on a new section of the output tape, hoping a permanent tape error is not encountered again.

B. DIGITIZING

The multichannel digitizing program had seven options or instructions which were entered by typing a single digit number (one through seven) on the teletype and depressing the carriage return button. If a further response was required the computer would indicate the format required. The options available were:

1 = Desire to enter new parameters.

2 = Start digitizing the analog input signals (normally actuated by manual switch on Ci 5000 control panel).

3 = Write an end-of-file mark.

4 = Rewind the tape to the load point (beginning).

5 = Skip the following number of end-of-file marks (format indicated for programmer response).

6 = Print the following amount of digitized data (format indicated for programmer response).

7 = Actuate the Digital-to-Analog subroutine for the next single block of data encountered and feed the signal to the strip chart recorder (which must be running prior to this option selection) connected to the analog patchboard on the Ci 5000.

In option 1, new parameters were entered into the XDS 9300. They were:

NREC = Maximum number of records to be digitized for one file. This parameter was normally set higher than necessary so start and stop of the digitizing could be controlled by a manual switch on the Ci 5000.

NSAMP = Total number of words desired in one block of digitized data divided by NCHAN, the number of channels digitized. This is the number of data samples of any one channel in one block of digitized data.

NCHAN = Number of channels of analog data input into the Ci 5000.

ITAPE = The identifying number of the tape drive in use. This number was set by a selector dial on the face of the tape drive unit.

In order to know the exact elapsed time of the analog data tape, a voice track was used. Knowing the amount of data digitized was important as frequently sampling rate and filter setting were varied for identical portions of analog data. An electric timer capable of measuring to the nearest one hundredth of a second was, also, of great value in obtaining duplicate portions of analog data.

Prior to digitizing, the entire analog tape signal was run through an oscilloscope to check the amplitudes of the signal. This was necessary to prevent "clipping" by driving the Hybrid Computer to saturation (i.e., exceeding the dynamic range of the system).

Prior to checking for "clipping", the raw (unamplified) analog signal was connected to an eight track strip chart recorder and the entire tape was recorded. This gave a visual record of the data for later comparison to a digital-to-analog strip chart to check for unwanted noise or other errors inadvertently introduced.

It was found that double-checking every step of the analog-to-digital conversion saved many hours of re-digitizing because of inadvertent blunders. Two people were required to operate the Hybrid Computer System efficiently. A written sequence of steps was, also, extremely helpful in maximum utilization of limited computer time.

V. DIGITAL DATA PROCESSING

A. DIGITAL MAGNETIC TAPE OPERATIONS

Magnetic tape operations on the IBM 360/67 Computer System did not require any manipulative effort as did the Hybrid Computer System. All manipulations of tapes were done by the computer center staff, whereas all tape manipulations on the Hybrid Computer System were done by users and not staff members. In order to have the tapes handled as desired, explicit instructions had to be given. There were two ways

instructions were given; one by a service request card addressed to the staff members identifying the tapes by serial numbers and whether the tapes were to be written onto or read off of, and another, by job control language (JCL) addressed to the computer giving far greater detailed instructions concerning the processing of the tapes.

1. Job Control Language Cards

Job control language (JCL) cards are special cards placed at the end of a program deck just before the final orange "slash star" card. These JCL cards provide information to the computer about tape mount number, tape identification, disposition of tape, identity of tape data file to process and order of data (format) on the tape. An example of a JCL card for tape processing would be:

```
//GO.FT04F001  DD UNIT=2400, VOL=SER=NPS274, LABEL=(1,SL),
//             DSNAME=JONZ96, DISP=(NEW,KEEP),DCB=(DEN=2,
//             RECFM=VS,BLKSIZE=8204)
```

The portions of the JCL card mentioned below will be the only portions subject to change for various tapes.

FT04 - This group indicates the logical unit (tape mount) on which the tape is to be placed. The two digit number (04 in this case) must match the number specified in the "READ" or "WRITE" instruction in the program for this tape. Once the logical unit has been specified for a tape in a program it cannot be changed during the run of the program.

F001 - This group indicates the sequential number of passes through the tape on a "READ" or "WRITE" instruction. The three digit number (001, in this case) may go up to 999 if needed.

UNIT=2400 - This group indicates the tape is a 9-track tape. The 7-track tape designation is UNIT=2400-1.

VOL=SER=NPS274 - This group identifies the volume of tape to process. In this case the tape has a serial number (NPS274). The serial identifier may be an alphanumeric group if the tape is an "external" tape (not from the IBM computer center tape pool).

LABEL = (1,SL) - This group identifies the file of the tape desired (1, in this case) and specifies that the tape has a standard label (SL). Usually this group will indicate the same number as the F001 group indicates, but not always. The F001 group must be incremented every time a file is processed (i.e., "read" or "write") but it is possible to create and write over or re-use a file by use of the same LABEL group more than once.

DSNAME=JONZ96 - This group specifies the data set name (DSNAME) which applies to the file of data specified by the LABEL group. Each file may have a unique name (JONZ96), or all files on a particular tape may have the same name. The important point is that whatever DSNAME a file is created (written) under, this same DSNAME must be used each time when reading the data from the tape.

DISP=(NEW,KEEP) - This group specifies the disposition of the tape when finished processing. Several selections are available but usually "NEW,KEEP" and "OLD,KEEP" are used (IBM Systems Reference Library, "Tape Labels").

DCB=(DEN=2,RECFM=VS,BLKSIZE=8204) - This group is the data control block (DCB). Recording density (DEN) is specified as 556 bytes per inch denoted by 2. Several other tape densities are available but 556 bytes per inch is normally used on this IBM installation. The tape density can be set by a dial on the face of the tape drive units in the Hybrid Computer System (ADC) and, also, specified in the JCL cards associated with the "write" statement of the IBM system programs. The tape record format (RECFM) is variable spaced (VS) when recording and digitizing on the ADC. The block size (BLKSIZE) specifies the exact number of <u>bytes</u> in one block of data (not words). The number of bytes specified (8204) was used because 2048 words (1024 per channel) per block were used and three words of program parameter data [KMAX (composed of two words) and NCHAN (one word)] were inserted before each block by the CONVERT program. The number of bytes in 2051 words is 8204. KMAX is the maximum number of words in the block (2048 words) and NCHAN is the number of channels (2).

2. <u>Multi-Volume Tape Operations</u>

At times, long records of data were processed which contained more than 1368 blocks of 2048 words which completely filled a volume of

tape. The IBM System will process more than one volume of tape provided the multi-volumes contained only one file of data. The following JCL cards allowed the processing of two tapes of data which contained only one file.

```
// GO.FT04F001 DD UNIT=2400,VOL=SER=(NPS274,NPS275),
//        LABEL=(1,SL),DSNAME=JONZ96,DISP=(NEW,KEEP),
//        DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
```

The above JCL cards indicate that file 1 located on tapes NPS 274 and continued on NPS 275 are to be processed using tape mount 4 and this is the first pass through the tape (by F001). Whether the tape processing is "READ" or "WRITE" cannot be determined by the JCL cards. The program statement which indicates the logical unit (tape mount) will, also, indicate the process (READ or WRITE) desired.

3. MULTI-FILE Tape Operations

Frequently, a number of short records of data were included on one volume of tape. Each record was a file, separated by an "End-of-file" mark at the end of each file on the tape. The JCL cards indicated which files were to be processed by the LABEL group of indicators. The JCL cards below are an example of processing (READ) three files of a volume of tape. There are four files on the tape but the second file is to be skipped. The tape is mounted on logical unit four.

```
// GO.FT04F001 DD UNIT=2400,VOL=SER=NPS274,LABEL=(1,SL),
//        DSNAME=JONZ96,DISP=(OLD,KEEP),DCB=(DEN=2,
//        RECFM=VS,BLKSIZE=8204)
// GO.FT04F002 DD UNIT=2400,VOL=SER=NPS274,LABEL=(3,SL),
//        DSNAME=JONZ96,DISP=(OLD,KEEP),DCB=(DEN=2,
//        RECFM=VS,BLKSIZE=8204)
// GO.FT04F003  DD UNIT=2400,VOL=SER=NPS274,LABEL=(4,SL),
//        DSNAME=JONZ96,DISP=(OLD,KEEP),DCB=(DEN=2,
//        RECFM=VS,BLKSIZE=8204)
```

4. MULTI-FILE and MULTI-VOLUME Tape Operations

The IBM System is limited in tape operations involving more than one file on more than one volume of tape. As mentioned before, there are procedures for processing more than one volume of tape with one file of data on it, and there are, also, procedures for processing more than one file of data on a single volume of tape. All these procedures were done in one run of a program which resulted in a great savings in time. However, there existed no procedure to process more than one file of data on more than one volume of tape in one run through the IBM Computer. Separate runs are required for each volume of tape containing more than one file of data. The only situation in which more than one volume of tape could be processed was when a single file "overflowed" onto an additional tape volume.

5. Common Tape Errors

The two most common problems encountered in processing tapes were faulty tape labels and machine failure due to static atmospheric charge.

Tape labels are placed on the IBM system tapes to identify them in the tape pool. Each tape has its own serial (e.g., NPS 274). The JCL cards identify and call for these tapes by these numbers. The computer checks the requested tape serial number against the tape serial number read. If the serials do not match, the job is rejected with an error statement of rejection printed on the output listing. The remedy is to request that the computer center staff re-label the faulty tape with the same serial number as before.

If the computer encounters a block of data it cannot read, it prints the entire block for diagnostic purposes. If an output listing has a block printed and it is a complete chaos of random symbols and numbers, it is likely this is the result of a spurious signal caused by static electric charge in the computer area. The computer area is air-conditioned to prevent this, but sometimes a static electric charge is encountered anyway. This problem occurs most often on days of low atmospheric humidity. The only remedy is to resubmit the job and hope no static electric charge is encountered.

B. SEVEN-TO-NINE TRACK CONVERSION

Digital tapes created by the Hybrid Computer System were written in 7-track form and the IBM Computer System operated almost exclusively in the 9-track format. In 7-track format, the binary number is processed by considering its octal representation made up of 3-bit digits, and in 9-track format the same binary number is processed by considering its hexadecimal representation made up of 4-bit digits. For this reason (computer incompatibility) all data derived from the ADC had to be converted to 9-track format by the use of program CONVERT (figure 1b and page 78).

The possibility of processing the data on the IBM Computer System in 7-track format was explored. For two reasons this was not considered feasible. The IBM Computer Center had only one 7-track tape drive unit (six units of the 9-track variety) and a minimum of two units were needed to read one digital data tape, compute the Fourier coefficients and write the Fourier coefficients onto another tape. Also, the 7-track tape unit was six times slower than the 9-track tape units and in view of the amount of data to be processed and the limited computer time available the 7-track data processing idea was rejected.

The IBM Computer processes data internally by use of assembler language. All 7-track and 9-track data is converted to assembler language internally for each job, thus the converting process is commonplace to the computer. The difficulty arose because of the requirement

for a specific order of data for each block of data. The requirement was because of the way in which the program, FTOR, read and processed the data. Standard subroutines existed for converting seven to nine track data (Zeleny and Brunell, 1969), but two parameters had to be placed in front of each block of 2048 words of digital data, KMAX and NCHAN. KMAX is the maximum number of words in the block of data and NCHAN is the number of channels digitized from the analog tape. With these requirements in mind, a program was written to convert one block of data at a time and place KMAX and NCHAN before each. The program would process all the blocks of data in one file at a time and then go to the next file of data until all files were converted that were desired. The program read from the 7-track tape and wrote onto another tape in the 9-track format, so two tapes (three, counting the analog tape) were then needed for each volume of data processed. But, another tape was necessary to store the computed Fourier coefficients. Thus, three digital tapes were necessary to process one volume (tape reel) of original 7-track data. The large library of tapes quickly became a problem and only careful bookkeeping avoided inadvertently processing the wrong tapes and possibly destroying data.

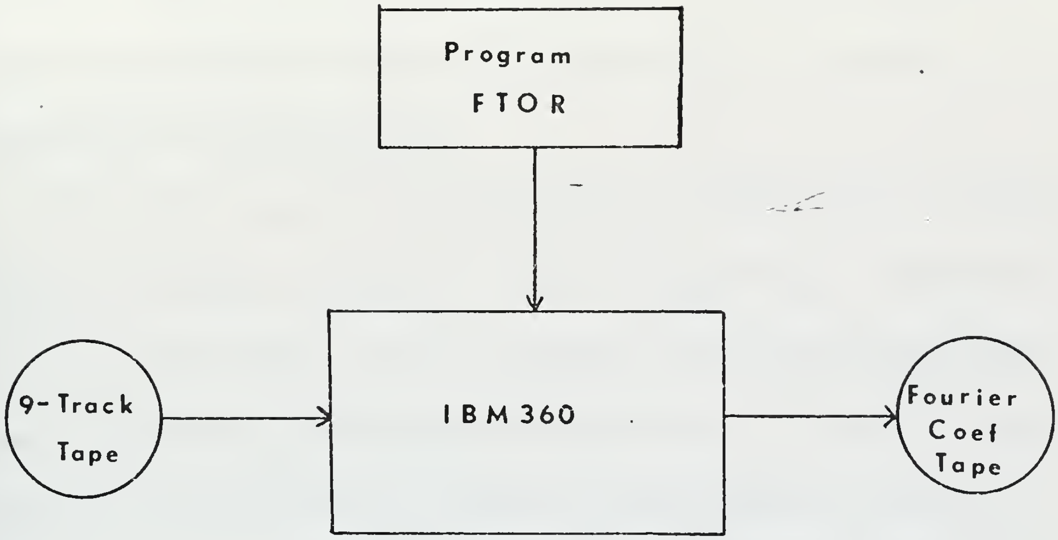
The output listing of the CONVERT program gave a complete listing (2048 data samples) of the first data block of each file processed and

the last block of the last file processed. The program also listed the sequential number of each block processed as a check on the completeness of the run of the program.

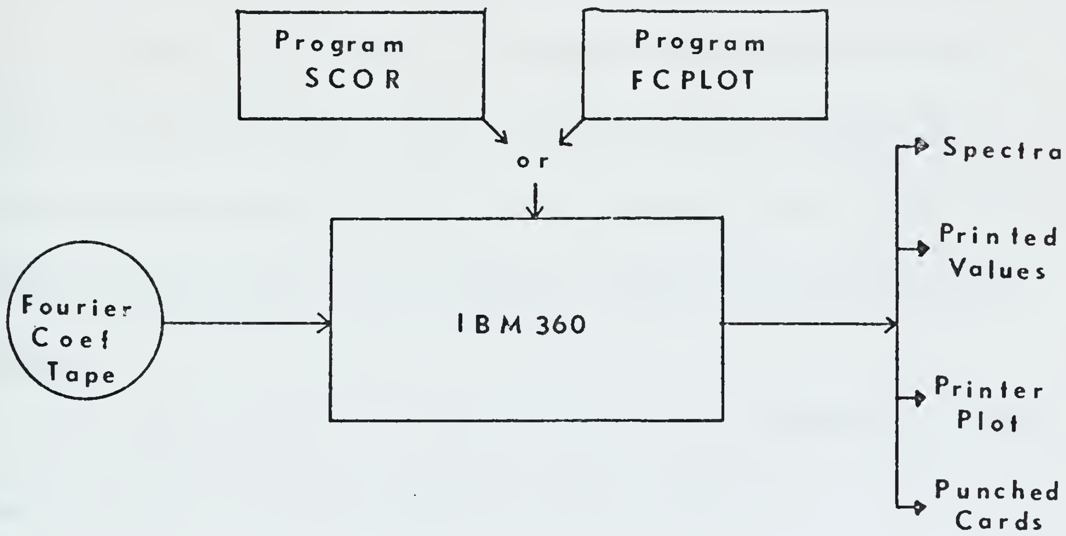
The CONVERT program is listed on page 78 and has complete annotation explaining all program changes necessary to convert any size 7-track block of data to a 9-track block of data putting KMAX and NCHAN before each block. After the program listing are JCL cards serving as examples for future reference of interested persons. The read and write JCL cards are similar to the JCL cards required for the FTOR program and may be used for that program with few changes.

C. FOURIER COEFFICIENTS COMPUTATIONS (FTOR PROGRAM)

The program, FTOR, calculated complex Fourier coefficients (a_n and b_n) from the 9-track digital tape and wrote them onto a new tape for further processing by the SCOR or FC PLOT programs (figure 6a). The "OCEAN" subroutine of FTOR read the input tape, one block at a time, then returned to the main program, processed the data and stored the Fourier Coefficients (Wilson, Boston and Denner, 1969). The entire program FTOR is listed in Wilson, et. al. (1969) with some amplifying information included. Appendix A of this thesis contains the preface comments of the FTOR program. One important change in the FTOR program is necessary to make the program compatible with the block size. In the "OCEAN 1" subroutine, KMAX must be set equal to the number of words in one block of data (Card 18).



a) Fourier Coefficient Computations



b) Spectral Displays and Outputs

Figure 6 Block Diagram of Analysis Procedures

In the "OCEAN 2" subroutine, the DIMENSION statement must be changed to reflect the value of KMAX (Card 23). These changes are the only ones necessary to adapt the FTOR program to a properly formatted 9-track digital tape.

All the UBC time series analysis programs (FTOR, SCOR, FC PLOT) are listed on faculty tape NPS 216, file 1-3 respectively. The reference previously sited (Wilson, et. al., 1969) gives more detailed information about tape NPS 216 and the programs listed therein. Source decks and listings of the programs are obtained via two programs contained on pages 74 and 77. It was discovered that the FTOR program on tape NPS 216 was programmed for a block size of 256 words. For this reason the FTOR program was run by the use of the source deck each time. However, SCOR and FC PLOT were usable in their recorded state on tape NPS 216, files 2 and 3, and were called by use of a single card rather than manipulating an entire box of cards for each computer run. To use the SCOR and FC PLOT programs directly from tape NPS 216, the card

// FORT.SYSIN DD *(the third card in any FORTRAN IV program)

was replaced by one of the following sets of cards.

a. SCOR Program

```
// FORT.SYSIN DD UNIT=2400,VOL=SER=NPS216,DISP=OLD,
//      LABEL=(2,SL),DSN=UBCSCOR
```

b. FC PLOT program

```
// FORT.SYSIN DD UNIT=2400,VOL=SER=NPS216,DISP=OLD,
//      LABEL=(3,SL),DSN=UBCFCPLT
```

The preamble comments of the FTOR program are listed in Appendix A and are self-explanatory with a few exceptions which require some amplification.

NCHAN - This is the number of channels taken off the analog tape and digitized onto the 7-track digital tape. This NCHAN must correspond to the NCHAN inserted immediately after KMAX and just before each data block of the 9-track digital tape created by the CONVERT program

INUNIT - This number must correspond to the logical unit (tape mount) selected for use in the JCL cards (FTOX group).

In the calibration cards (KCHAN number of cards), "primary A to D Channel" refers to the channel used on the analog patchboard in the Hybrid Computer System. Normally the primary channel is a sequential number starting with one for the first channel (usually the lowest channel number used on the analog tape) digitized. In the alphanumeric section of these cards it was found useful to place unique identifying parameters such as sampling rate, filter setting and analog tape (channel) numbers. The alphanumeric section is printed as the title of all output graphs. Thus, a unique identifier is necessary to assist in bookkeeping procedures associated with numerous output graphs normally required.

It was found that approximately 22 seconds of computer time was required for compiling the FTOR program and approximately 1.07 seconds per block was required for a block size of 2048 words each. The memory space usually required for FTOR was 156K bytes.

Because of the "SKIPFILE" subroutine in FTOR, it was necessary to include JCL cards for <u>every</u> file of data on a 9-track tape. Usually programs depend upon JCL cards to select the data files for processing, but FTOR, as well as SCOR and FCPLOT, have internal selection of data files based on the analysis cards included in the control card section of the program card deck.

D. SPECTRA PLOTTING (SCOR AND FCPLOT PROGRAMS)

1. General

The two plotting programs, SCOR and FCPLOT, read Fourier coefficients from the output tape of the FTOR program (figure 6b) and plotted various spectra. The SCOR program gave power spectra and cross spectra and the FCPLOT program gave printer and ink drawings of spectra plots of Fourier coefficients versus amplitudes. Both programs processed a single reel of digital tape (1368 blocks of 2048 words each) in less than 10 minutes of computer time. The computer time varied with the type of plots selected.

2. SCOR Program

The SCOR program may be called directly from the faculty tape NPS 216, file 2 or a source deck may be used. The block size of

the digital 9-track data tape (derived from the CONVERT program) was of no consequence as the input to the SCOR program was the Fourier coefficient tape which was of uniform format regardless of the block size used in the 9-track digital input tape.

The graphic output of SCOR was spectrum and cross spectrum. The axes of the graphic outputs were specified rather than allow the graphic subroutine to scale the graphs. A uniform selection of values for axes for all graphic outputs allowed easy comparison by simply overlaying the spectra. Two types of bandwidth were available, exponential and constant. The exponential bandwidth took increments of approximately one-half octave for a maximum of 32 bandwidths (16 octaves). This type bandwidth appeared as a constant bandwidth on a log-log plot due to the nature of the axis units (logarithmic). Phase corrections were an available input but were not used in this study.

Appendix B contains the preamble comments to the SCOR program. All input parameters are explained fully there, but one section of cards requires clarification. The control card group entitled "SUBSEQUENT ICMAX CARDS" indicate what graphic output is desired; spectra, cross spectra or both. To obtain a spectrum of a single channel input, a cross spectrum of that channel (1, for example) with itself is called for. For two channels (1 and 2), a spectrum of channel one and a spectrum of channel two as well as a cross spectrum of channels one and two are obtained by the following entries on these two cards.

First card: 1 1 2

Second card: 2 2

Cross spectra are computed only if each channel appears in the list on the other channel's card.

The SCOR program required approximately 162K bytes of memory and 120K bytes of core to compile the program.

3. FC PLOT Program

The FC PLOT program produced printer and ink drawings of amplitudes of Fourier coefficients, and ink drawings of power spectra. Appendix C contains the preamble comments of FC PLOT. All required input parameters are clearly stated in these comments. The parameter NPDCDE gives the maximum number of spectral estimates per decade desired. This parameter allows a large range of flexibility in selecting a bandwidth and implementing information derived from the consideration of confidence limits and degrees of freedom (as discussed in Section II).

The FC PLOT program required approximately 146K bytes of storage.

Wilson, et. al., contains a complete listing of three of the previously mentioned programs (FTOR, SCOR, FCPLOT) along with samples of typical printed and plotted output. The faculty tape on which these programs are recorded (NPS 216) is also fully described therein.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. ANALOG-TO-DIGITAL CONVERSION PROCESS

The following conclusions and recommendations concerning the ADC (Hybrid Computer System) for the frequency range of interest are presented.

1. Conclusions

a. Noise introduced into the analog signal by the analog patch-board, analog filter and signal amplifier is excessive for accurate digital output for the frequency range of interest. Except for the noise, the Hybrid Computer System is adequate for analog-to-digital conversion.

b. The ADC tape drives which appeared to be limited to a maximum of 4000 samples per second is a limiting factor for long analog records requiring high sampling rates.

c. A digital-to-analog program is included in the analog-to-digital program and operated successfully on the Hybrid Computer System, however a feature to compute and indicate sampling rate is necessary for positive tape verification.

2. Recommendations

a. A new method must be devised to place the analog signal into the ADC and by-pass the aforementioned sources of noise.

b. Fast response tape drive units should be installed in the Hybrid Computer System to allow for higher sampling rates.

c. A systematic noise analysis should be undertaken to find and eliminate other sources of noise in the ADC.

d. A sophisticated verification program is necessary to check the results of the digitizing effort on the XDS 9300 for the 7-track tape. A digital-to-analog program currently exists but additional operations are needed to compute the mean, variance, skewness, coefficient of excess, sampling rate and maximum frequency encountered in the 7-track digital tape. This program would result in an economical use of computer and experimental time.

B. DIGITAL DATA PROCESS

The following conclusions and recommendations concerning digital data processing are presented.

1. Conclusions

a. The existing programs CONVERT, FTOR, SCOR and FCPLOT are excellent for reducing digital time series data to spectra and associated printed values.

b. The IBM 360/67 computer system at NPS is adequate to process large quantities of digital time series data.

2. Recommendations

a. A verification program to compute mean, variance, skewness, coefficient of excess, sampling rate and maximum frequency is

necessary to ensure that the 9-track digital tape used as the input to the FTOR program is free of any spurious noise signals. In addition, the information computed will assist in further analysis of the digital data.

b. A program to convert the digital signal (9-track tape) to an analog presentation is necessary in order to provide a constructed analog signal chart to compare with the original analog signal chart to ascertain the effects on the data of the preceding data reduction steps.

c. Full time programming assistance of high quality (Ph. D. Degree) should be made available to students. It would be most advantageous to have one person with broad programming skills available to students conducting research on similar topics (time series analysis, geophysical statistics).

C. GENERAL

A calibration procedure for the entire system (from input to ADC to IBM 360/67 output) should be carried out. This would involve putting signals of known characteristics (sine waves, square waves, for example) into the system and observing the output. This calibration should involve various combinations of amplifiers and filters to check for noise sources; a variety of sampling rates to ascertain maximum reliable sampling rates;

single channel and multi-channel digitizations to determine the maximum number of channels that can be simultaneously digitized and finally, different signal levels to check minimum and maximum signal levels required for successful digitizations.

APPENDIX A - FTOR

```
C FOURIER TRANSFORM OF TIME SERIES DATA SUPPLIED THROUGH
C 'OCEAN' SUBROUTINES USING P-K FORT FAST FOURIER TRANSFORM
C SUBROUTINE (SHARE SDA3465) IN THE IBM SYSTEM 360 MODEL 67.
C
C LAST REVISION JANUARY 24,1969              JOHN GARRETT
C
C   NBLOCK BLOCKS OF 2**NPOW SAMPLES EACH ARE READ FOR KCHAN OF THE
C NCHAN CHANNELS AVAILABLE TO THE 'OCEAN' SUBROUTINES.  THE CONTENTS OF
C ANY CHANNEL MAY BE REPLACED BY A LINEAR COMBINATION OF ITSELF WITH ANY
C OTHER CHANNEL.
C
C  FOR EACH BLOCK 2**(NPOW-1) COMPLEX FOURIER COEFFICIENTS ARE
C COMPUTED FOR EACH OF THE KCHAN CHANNELS.  THESE ARE THEN WRITTEN ON THE
C OUTPUT (TAPE) 03 IN THE FORMAT DESCRIBED BELOW. IN ADDITION THE
C COEFFICIENTS MAY BE SUMMED IN GROUPS OF (2**(NPOW-1))/32 AND
C PRINTED OUT.
C
C  ADDITIONAL OPTIONS ARE DESCRIBED UNDER THE RELEVANT CONTROL
C PARAMETERS BELOW.
C
C     IT SHOULD BE NOTED THAT THE COEFFICIENTS PRODUCED ARE THOSE OF THE
C FOURIER SERIES
C     Y(J) = SUM OVER K = 0,N/2 OF REAL PARTS OF
C              (C(K)*EXP((2*PI*I/N)*J*K))
C     WITH J = 0,N-1,Y(J)REAL,AND I = SQRT(-1)
C
C THE FOLLOWING SUBROUTINES ARE REQUIRED
C      OCEAN1,OCEAN2,OCEAN3,RWUNLD
C      SKPFL
C      CONVOL
C      USCRMB
C      P-K FORT
C
C THE FOLLOWING LOGICAL INPUT/OUTPUT DEVICES ARE USED IN THIS PROGRAM
C      2 = SCRATCH TAPE FOR TEMPORARY STORAGE OF COEFFICIENTS IF
C          LCFR=1 BELOW
C      3 = OUTPUT (TAPE) FOR COEFFICIENTS
C      5 = (CARD) INPUT FOR CONTROL PARAMETERS
C      6 = PRINTED OUTPUT
C      INUNIT = INPUT TAPE OF TIME SERIES DATA FOR 'OCEAN' SUBROUTINES
C
C INPUT INFORMATION REQUIRED
C    *****IMPORTANT NOTE. READ THE COMMENT CARDS IN THE OCEAN
C    SUB-ROUTINE.  SOME FACTORS WILL HAVE TO BE CHANGED TO FIT BLKSIZE.
C     FIRST DATA CARD IN COLUMN NUMBER
C     1-9    IDUSER = USER IDENTIFICATION NUMBER (9-DIGIT INTEGER)
C     14-15 NCHAN = NUMBER OF CHANNELS DIGITIZED ON OCEAN TAPE
C     25     NTYPE = (NOT RELEVENT. SET TO ZERO.)
```

```
C     34-35 INFILE = FILE NUMBER OF DATA ON OCEAN TAPE
C     44-45 INUNIT = NUMBER OF UNIT ON WHICH INPUT TAPE IS MOUNTED
C     55    NSEARH = (NOT RELEVENT. SET TO ZERO.)
C     61-70 SAMFRQ = SAMPLING FREQUENCY OF DIGITIZING  (SAMPLES/SECOND)
C                    (MUST  INCLUDE  A DECIMAL POINT )
C     SECOND DATA CARD
C     4-5   NBLOCK = NUMBER OF BLOCKS DESIRED
C     14-15 NPOW- MAXIMUM NUMBERS OF SAMPLES PER BLOCK WILL BE 2**NPOW,
C              MAX NPOW IS 13 (8192 SAMPLES/BLOCK) BUT NPOW WILL BE
C              REDUCED UNTIL (2**NPOW)*KCHAN WILL FIT IN MEMORY. FOR
C              KCHAN OF 10 THIS WILL GIVE NPOW = 10 (1024 SAMPLES/BLOCK).
C     24-25 MTAPE =+1 FOR OUTPUT TAPE TO BE WRITTEN
C                 =-1 FOR NO OUTPUT TAPE
C     34-35 NFILE - OUTPUT COEFFICIENTS WILL BE NFILE-TH FILE ON TAPE
C     43-45 MAXERR = (NOT RELEVENT. SET TO ZERO.)
C     54-55 MPRINT = -1 SUPPRESSES SUMMARY COEFFICIENTS PRINT OUT
C                  = 0 OR GREATER PERMITS PRINT OUT
C     THIRD DATA CARD
C     4-5   KCHAN = NUMBER OF CHANNELS TO BE TRANSFORMED (MAX 10)
C     15    LOFR = 2 IF COEFFICIENTS TO BE COMPUTED FROM DATA SMOOTHED
C                  AND SUBSAMPLED (DECIMATED) USING CONVOL SUBROUTINE.
C                  WEIGHTS USED IN SMOOTHING AND DECIMATING FACTOR ARE
C                  DETERMINED BY CHOICE OF CONVOL USED.
C          = 1 IF ALTERNATE BLOCKS TO BE MADE UP OF SAMPLES FROM DATA
C                  SMOOTHED AND DECIMATED USING CONVOL SUBROUTINE.
C                  COEFFICIENTS WILL APPEAR ON OUTPUT TAPE IN FILE
C                  IMMEDIATELY FOLLOWING THAT CONTAINING RESULTS FROM
C                  UNSMOOTHED DATA
C               = 0 IF DATA TO BE LEFT ALONE
C     25    IHANN = 1 IF FOURIER COEFFICIENTS TO BE HANNED AND
C                   NORMALIZED (*SQRT(8/3))
C                 = 0 IF NOT
C
C     NEXT KCHAN CARDS
C     1-5   NO. OF PRIMARY A TO D CHANNEL
C     6-10  NO. OF SECONDARY A TO D CHANNEL
C     11-20 CALIBRATION ASSOCIATED WITH THE PRIMARY A TO D CHANNEL
C     21-30 CALIBRATION ASSOCIATED WITH THE SECONDARY A TO D CHANNEL
C     31-66 ALPHAMERIC NAME OF RESULTING PRIMARY CHANNEL
C     71-78 8 CHARACTER NAME OF UNITS FOR RESULTING PRIMARY CHANNEL
C
C THE DATA TRANSFORMED AS THE PRIMARY CHANNEL IS THEN
C
C     CALIBRATION1 X VALUE OF PRIMARY + CALIBRATION2 X VALUE OF
C     SECONDARY CHANNEL
C
C
C A SECOND SET OF DATA CARDS WILL PRODUCE A SECOND ANALYSIS. A BLANK
```

```
C CARD TERMINATES THE RUN.
C
C FORMAT OF OUTPUT TAPE FOR EACH BLOCK TRANSFORMED IS AS FOLLOWS
C     FIRST LOGICAL RECORD IS AN ARRAY OF 256 WORDS CALLED
C    ARTAPE
C     ARTAPE(1)= IDUSER
C     ARTAPE(2)= BLOCK NUMBER
C     ARTAPE(3) = NUMBER OF SAMPLES /BLOCK
C     ARTAPE(4) = NTAP (SEE BELOW)
C     ARTAPE(5) = NUMBER 6F CHANNELS TRANSFORMED
C     ARTAPE(6) = SAMPLING FREQUENCY
C     ARTAPE(10) = IHANN
C     ARTAPE(10+K) = MCHAN(K)
C     ARTAPE(31+9(K-1)) = ACHNAM(K)     (9A4)
C     ARTAPE(121+2(K-1)) = AUNITS(1,K)    (2A4)
C     ARTAPE(140+K) = CAL(K)
C
C     NEXT NTAP LOGICAL RECORDS OF 256 WORDS EACH CALLED
C    TAPRAY AND CONSIST OF
C     1 WORD CONTAINING INTEGER HARMONIC NO (0 TO IBLOCK/2) FOLLOWED BY
C     2*KCHAN WORDS CONTAINING FOR EACH OF THE KCHAN CHANNELS THE
C       REAL PART OF THE FOURIER COEFF  AT THIS HARMONIC(FIRST WORD)
C       FOLLOWED BY THE IMAGINARY PART(SECOND WORD).
C     ONLY COMPLETE SEQUENCES OF 1+(2*KCHAN) WORDS ARE INCLUDED IN A
C     TAPRAY SO THAT THE LAST FEW WORDS MAY CONTAIN ZEROS
C
C AN END OF FILE IS WRITTEN ON THE OUTPUT TAPE AT THE END OF A SEQUENCE
C     OF BLOCKS
C
C  J.F. GARRETT                      INSTITUTE OF OCEANOGRAPHY
C  J.R. WILSON                       UNIVERSITY OF BRITISH COLUMBIA
C                                    VANCOUVER 8,CANADA
```

```
THE FOLLOWING TWO CARDS ARE TYPICAL CONTROL CARDS. NOTE SPECIAL REQUEST
FOR 'FORT=120K'.
//     EXEC FORTCLGP,REGION.FORT=120K,REGION.GO=175K,TIME.GO=10
//FORT.SYSIN DD *
C
C SPECTRUM AND CROSS SPECTRUM STATISTICS FROM FOURIER
C COEFFICIENT TAPE PRODUCED BY 'FTOR' PROGRAM ON IBM
C SYSTEM 360 MODEL 67
C
C LAST REVISION JANUARY 27,1969          JOHN GARRETT
C
C THIS PROGRAM READS FOURIER COEFFICIENTS FROM TAPE PRODUCED BY FTOR
C PROGRAM, AND FROM THE APPROPRIATE SUMS OF THESE PRODUCES SPECTRA AND
C COSPECTRA. THE SUMS USED MAY BE FIXED WITH FREQUENCY OR MAY GO IN HALF
C OCTAVES FROM A SPECIFIED LOW FREQUENCY. AN AVERAGE, STANDARD DEVIATION
C AND LINEAR COEFFICIENT OF REGRESSION OVER THE IBMAX BLOCKS USED (SEE
C FTOR DESCRIPTION) ARE GIVEN FOR EACH VALUE OF SPECTRAL DENSITY.
C AT EACH FREQUENCY, THE COSPECTRUM BETWEEN (1) AND (2) IS GIVEN BY
C       ( R(1)*R(2) + I(1)*I(2))/ 2.0
C     A VARIETY OF PLOTTED OUTPUT IS AVAILABLE.  IN ALL A HORIZONTAL BAR
C A VERTICAL BAR INDICATES THE EXPECTED STANDARD DEVIATION OF THE
C INDICATES THE FREQUENCY INTERVAL INCLUDED IN THE ESTIMATE PLOTTED, AND
C OF SERIES (N) AT THAT FREQUENCY
C AND THE QUADRATURE SPECTRUM BY
C
C       ( R(2)*I(1) - R(1)* I(2))/ 2.0
C WHERE ( R(N) + (I(N)*SQRT(-1)) ) IS THE COMPLEX FOURIER COEFFICIENT
C ESTIMATE (= STD.DEV. OF BLOCKS AVERAGED TO GIVE ESTIMATE/ SQRT(NUMBER
C     OF BLOCKS))
C
C THE FOLLOWING SUBROUTINES MUST BE SUPPLIED BY USER
C      PHASES
C      PLVAL,TIC,LABEL
C
C THE FOLLOWING LOGICAL INPUT/OUTPUT UNITS ARE USED BY THIS PROGRAM
C      3= (TAPE) SUPPLYING COEFFICIENTS AND IDENTIFICATION AS
C         PRODUCED BY FTOR
C      5= (CARDS) CONTROL PARAMETERS
C      6= PRINTED OUTPUT
C
C THE FOLLOWING INPUT IS REQUIRED
C
C A CARD IS REQUIRED TO IDENTIFY YOUR GRAPHICAL OUTPUT FOR THE COMPUTING
C CENTRE STAFF. IT MUST BE PRESENT WHETHER PLOTS ARE PRODUCED OR NOT.
C THE FIRST 72 COLUMNS OF THIS CARD WILL BE REPRODUCED ON THE BEGINNING
C OF YOUR PLOT. THIS CARD APPEARS ONLY ONCE IN THE JOB AND IS THE FIRST
C DATA CARD. THE FOLLOWING SET OF CARDS IS PRESENT FOR EACH FILE OF
C FOURIER COEFFICIENTS TO BE PROCESSED.
```

```
C
C   FIRST CARD,IN COLUMN
C      1-9    IDUSER = USER IDENTIFICATION NUMBER FOR DATA DESIRED
C      14-15 ICMAX = NUMBER OF CHANNELS TO BE USED (MAX 10)
C      24-25 IBMAX = NUMBER OF DATA BLOCKS FOR STATISTICS
C     34-35 IBSTAR = STATISTICS START WITH BLOCK NO. IBSTAR
C     44-45 NFILE = DATA IS IN NFILE-TH FILE ON FOURIER COEFFICIENT TAPE
C      54     IAXIS = 0 (BLANK) IF PLOT AXES TO BE SET BY PROGRAM
C                   = 1 IF AXES TO BE SET BY USER
C      55     IPLOT = 0 IF NO PLOTTED OUTPUT DESIRED
C                =1 IF SPECTRAL DENSITY TO BE PLOTTED AGAINST FREQUENCY
C                =2 IF LOG10 SPECTRAL DENSITY TO BE PLOTTED AGAINST FREQUENCY
C                =3 IF LOG10 SPECTRAL DENSITY TO BE PLOTTED AGAINST LOG10
C                     FREQUENCY
C                =4 IF      (FREQ*SPECTRAL DENSITY) TO BE PLOTTED
C                   AGAINST LOG10 FREQUENCY
C                =5 SAME AS IPLOT=1 EXCEPT COHERENCE AND PHASE PLOTTED
C                   INSTEAD OF CO AND QUAD SPECTRA
C                =6 SAME AS =2 EXCEPT COHERENCE AND PHASE PLOTTED INSTEAD
C                     OF CO AND QUAD
C                =7 SAME AS 3 EXCEPT COHERENCE AND PHASE INSTEAD OF CO+QU
C                = 8 SAME AS 4 WITH COHERENCE AND PHASE INSTEAD OF CO + QU
C      65     IPHASE = 0 FOR NO PHASE CORRECTIONS
C                 = 1 FOR PHASES TO BE CORRECTED.
C
C   CARD INSERTED ONLY IF IAXIS = 1
C      IN COLUMN
C     1-10   VALUE OF ORIGIN FOR SPECTRUM AND COSPECTRUM AXIS(F10.)
C     11-20  UNITS PER INCH FOR SPECTRUM AND COSPECTRUM AXIS (F10.)
C                     AXIS WILL BE 5.00 INCHES LONG
C     21-30  VALUE OF ORIGIN FOR QUADSPECTRUM AXIS  (F10.)
C     31-40  UNITS PER INCH FOR QUAD SPECTRUM AXIS (F10.) AXIS WILL BE
C                   5.00 INCHES LONG.  (COHERENCE AND PHASE WILL BE
C                   SCALED BY PROGRAM IF PLOTTED INSTEAD OF CO AND QUAD.)
C     41-50 VALUES OF ORIGIN FOR FREQUENCY AXIS (F10. )
C     51-60  UNITS PER INCH FOR FREQUENCY AXIS (F10.)
C     61-70  LENGTH OF FREQUENCY AXIS IN INCHES (F10.)
C   N.B. WHEN LOG10 PLOTS HAVE BEEN REQUESTED NUMBERS ABOVE MUST ALL
C     REFER TO LOG10,.E.G. UNITS PERINCH = 1.00 MEANS 1 DECADE PER INCH
C
C NEXT CARD,IN COLUMN
C      5      LINOCT = 0 FOR CONSTANT BANDWIDTH,GIVEN BY BANDW BELOW
C                    = 1 FOR EXPONENTIAL BANDWIDTHS ( GIVES LOG10 FREQ.
C                        SCALE IN ALL PLOTS   )
C      6-15   STRFRQ = APPROXIMATE CENTER FREQUENCY OF FIRST POINT OF
C                      SPECTRUM, IN HERTZ. (MUST INCUDE A DECIMAL POINT)
C                      FIRST BAND WILL INCLUDE ZEROTH HARMONIC IF STRFRQ
C                      IS LESS THAN BANDW
```

```
C     16-25 BANDW = APPROX. BANDWIDTH FOR FIXED BANDWIDTH SPECTRA,
C                   IN HERTZ. (MUST INCLUDE A DECIMAL POINT)
C     30      INDOW = 1 IF FOURIER COEFFCIENTS TO BE HANNED BEFORE
C                   SPECTRA COMPUTED
C                 = 0 IF NOT
C   SUBSEQUENT ICMAX CARDS
C     4-5   CHANNEL NUMBER OF A CHANNEL FOR WHICH SPECTRA ARE WANTED
C           NUMBER IS USUALLY NUMBER OF A-D CHANNEL USED FOR CONVERSION
C     14-15,19-20,24-25,29-30 TO 59-60 , CHANNEL NUMBERS OF UP TO ICMAX
C           CHANNELS FOR WHICH CROSS SPECTRA WITH CHANNEL GIVEN IN
C           COLS.4-5 ARE DESIRED. SPECTRUM IS HERE CONSIDERED AS CROSS
C           SPECTRUM OF CHANNEL WITH ITSELF, I.E. THE NUMBER IN 4-5
C           MUST REAPPEAR IF SPECTRUM IS TO BE OBTAINED. ALSO,CROSS
C           SPECTRA ARE DONE ONLY IF EACH CHANNEL APPEARS IN THE LIST
C           ON THE OTHER CHANNELS CARD. THUS TO GET SPECTRUM FOR
C           CHANNEL 2 AND CROSS SPECTRUM BETWEEN 2 AND CHANNEL 8, THERE
C           MUST BE A CARD WITH  2 IN COL.5 AND BOTH 2 AND 8 IN THE LIST
C           AND ANOTHER CARD WITH 8 IN COL.5 AND 2 IN THE LIST.
C
C   PHASE CORRECTION DECK( INSERT ONLY IF IPHASE NOT ZERO )
C     PHASE CORRECTIONS APPLIED WILL BE OBTAINED BY LINEAR INTERPOLATION
C     BETWEEN VALUES SUPPLIED AT FREQUENCIES LISTED BELOW
C   FIRST K CARDS( K LESS THAN 6 )
C     1-10,11-20,....,71-80 , FREQUENCIES( F10.4 ) AT WHICH PHASE
C       CORRECTIONS ARE TO BE SUPPLIED ( UP TO 48 OF THEM )
C         IF LESS THAN THE FULL 48 FREQUENCIES ARE SUPPLIED, THEN
C           THE LAST FREQUENCY MUST BE LEFT BLANK.
C   SUBSEQUENT ICMAX SETS OF K CARDS EACH
C     1-10,11-20,....,71-80 , PHASE CORRECTIONS( F10.4 ) TO BE APPLIED
C       AT THE ABOVE FREQUENCIES. EACH SET CONTAINS THE CORRECTIONS
C         FOR A GIVEN CHANNEL, AND THE SETS ARE IN THE SAME ORDER AS THE
C         SPECTRUM CARDS. IF NO CORRECTIONS ARE TO BE APPLIED TO A
C         CHANNEL, THE K CARDS FOR THAT CHANNEL SHOULD BE BLANK.
C             CORRECTIONS MUST BE IN RADIANS. A POSITIVE CORRECTION WILL
C         CAUSE THE CORRECTED PHASE TO LEAD THE UNCORRECTED ONE.
C
C   LAST CARD MUST BE BLANK UNLESS ANOTHER FILE IS TO BE PROCESSED, IN
C   WHICH CASE A COMPLETE NEW SEQUENCE OF CARDS APPROPRIATE TO THE NEW
C   FILE SHOULD FOLLOW.
```

APPENDIX C - FC PLOT

```
C     PRINTER PLOT OF AMPLITUDE FROM FOURIER COEFFICIENT TAPE
C
C     THE FIRST INPUT CARD SHOULD CONTAIN UP TO 72 CHARACTERS OF PLOT
C     IDENTIFICATION FOR USE BY THE COMPUTING CENTER STAFF AND IS
C     REPRODUCED ON THE PLOTTER OUTPUT. THIS CARD MUST BE PRESENT
C     WHETHER PLOTS ARE PRODUCED OR NOT. IT IS PRESENT ONLY ONCE IN THE
C     DECK. THE FOLLOWING SET OF CARDS IS PRESENT FOR EACH FILE OF
C     FOURIER COEFFICIENTS PROCESSED.
C
C     CONTROL CARD DECK MAKEUP
C
C     1)    KFILE,KCHAN,KSTART,KSTOP,KPLOT,KRULE,KLIST,KPUNCH,LOGLIN,
C           LOGLOG                                                 (10I5)
C
C     WHERE,
C
C           KFILE = NO. OF FILE ON FOURIER COEFFICIENT TAPE
C
C           KCHAN = NO. OF FOURIER COEFFICIENT TAPE CHANNEL DESIRED
C
C           KSTART = FIRST BLOCK TO BE INCLUDED IN ANANYSIS
C
C           KSTOP = LAST BLOCK TO BE INCLUDED IN ANALYSIS
C
C           KPLOT = 1 FOR CALCOMP PLOT
C                 = 0 FOR NO CALCOMP PLOT
C
C           KRULE = 1 FOR A COLUMN OF PERIODS PER INCH ON THE PLOT
C                 = 0 IF THIS IS NOT DESIRED
C
C           KLIST = 1 FOR A PRINTER PLOT
C                 = 0 TO SUPPRESS THE PRINTER PLOT
C
C           KPUNCH = 1 TO PUNCH A BINARY DECK OF THE INTERMEDIATE SUMS
C                  = 0 OTHERWISE
C
C           LOGLIN = 1 TO OBTAIN A LOG VS LINEAR SPECTRUM PLOT
C                  = 0 OTHERWISE
C
C           LOGLOG = 1 TO OBTAIN A LOG LOG SPECTRUM PLOT
C                  = 0 OTHERWISE
C
C     2)    TITLE CARD WITH UP TO 72 COLUMNS OF IDENTIFICATION FOR
C           PRINTER OUTPUT AND PLOTS
C
C     THE FOLLOWING CARD IS PRESENT ONLY IF LOGLIN = 1 ON CARD 1)
C
C     3)    NDCDE,NPDCDE,FSTART,DPINCH                        (2I10,2F10.0)
```

```
C
C     WHERE,
C
C          NDCDE = NO. OF FREQUENCY DECADES TO BE PLOTTED
C
C          NPDCDE = MAXIMUM DESIRED NO. OF SPECTRAL ESTIMATES PER DECADE
C
C          FSTART = ANOTATION TO APPEAR ON FIRST FREQUENCY DECADE ON
C                   PLOT
C
C          DPINCH = NO. OF FREQUENCY DECADES TO BE PLOTTED PER INCH
C
C     THE FOLLOWING CARD IS PRESENT ONLY IF LOGLOG = 1 ON CARD 1)
C
C     4)   NDCDE,NPDCDE,FSTART,DPINCH,NYDCDE,DY  (2I10,2F10.0,I10,F10.0)
C
C     WHERE,
C
C          NDCDE = NO. OF FREQUENCY DECADES TO BE PLOTTED
C
C          NPDCDE = MAXIMUM DESIRED NO. OF SPECTRAL ESTIMATES PER DECADE
C
C          FSTART = ANOTATION TO APPEAR ON FIRST FREQUENCY DECADE ON
C                   PLOT
C
C          DPINCH = NO. OF FREQUENCY DECADES TO BE PLOTTED PER INCH
C
C          NYDCDE = NO. OF DECADES TO BE PLOTTED ON SPECTRAL DENSITY
C                   AXIS
C
C          DY = NO. OF DECADES PER INCH TO BE PLOTTED ON SPECTRAL
C               DENSITY AXIS
C
C
C     INPUT TAPE IS ON LOGICAL UNIT 9
C
C          A BLANK CARD WILL TERMINATE THE RUN OR ANOTHER COMPLETE SET
C     OF CARDS WILL DO A SECOND ANALYSIS
C
C          THE PROGRAM DOES AN ANALYSIS ON THE FOURIER COEFFICIENTS
C     DEFINED BY THE FIRST CONTROL CARD. THE FOURIER COEFFICIENT NO.,
C     ITS FREQUENCY, ITS MEAN AMPLITUDE AND ITS 95 PERCENT CONFIDENCE
C     INTERVAL ARE PRINTED. THE MEAN AND 95 CONFIDENCE INTERVAL ARE
C     PLOTTED ON THE PRINTER. ONLY THE MEAN IS PLOTTED ON THE CALCOMP
C     PLOTTER.
C
C          THE PROGRAM WILL HANDLE ONLY ONE CHANNEL AT A TIME FROM THE
C     FOURIER COEFFICIENT TAPE
```

APPENDIX D - EXAMPLE PROGRAM CONTROL CARDS

```
THE FOLLOWING LISTING OF CARDS AND PARAMETERS ARE REPRESENTATIVE OF A COMPLETE
ANALYSIS OF ANALOG DATA FROM ANALOG-TO-DIGITAL CONVERSION TO SPECTRA OUTPUT.

I   ANALOG-TO-DIGITAL
THE MULTI-CHANNEL A-TO-D PROGRAM HAD THE FOLLOWING PARAMETER INPUTS:
              NREC=1000
              NSAMP=1024  (WORDS IN 1 BLK / NCHAN)
              NCHAN=2
              ITAPE=1   (TAPE MOUNT)
SEVEN TRACK DIGITAL TAPE IS THE OUTPUT OF THIS STEP.
THE SAMPLING RATE IS SET BY THE ANALOG SECTION OF THE HYBRID COMPUTER(CI 5000).


II   CONVERT
THE CONVERT PROGRAM PLACES KMAX=2048 AND NCHAN=2 IN FRONT OF EACH BLOCK OF
DIGITAL DATA (2048 WORDS). THE INPUT TAPE IS THE 7-TRACK TAPE NAMED JONZ76 AND
THE OUTPUT IS THE 9-TRACK TAPE NPS274 CALLED JONZ96.  THE FOLLOWING CARDS WERE
USED TO PROCESS 5 FILES OF DATA.

//JONZ0088 JOB (0070,0353FP,OP94),'ROBT D JONES BOX J'
//CONVERT EXEC FORTCALG,REGION.GO=100K,TIME.GO=10
//FORT.SYSIN DD *

INSERT THE CONVERT PROGRAM DECK HERE

//GO.FT02F001 DD UNIT=2400-1,VOL=SER=JONZ76,LABEL=(1,NL),
//               DISP=(OLD,KEEP),DCB=(DEN=1,RECFM=F,BLKSIZE=8192)
//GO.FT04F001 DD UNIT=2400,VOL=SER=NPS274,LABEL=(,SL),DSNAME=JONZ96,
//               DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT02F002 DD UNIT=2400-1,VOL=SER=JONZ76,LABEL=(2,NL),
//               DISP=(OLD,KEEP),DCB=(DEN=1,RECFM=F,BLKSIZE=8192)
//GO.FT04F002 DD UNIT=2400,VOL=SER=NPS274,LABEL=(2,SL),DSNAME=JONZ96,
//               DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT02F003 DD UNIT=2400-1,VOL=SER=JONZ76,LABEL=(3,NL),
//               DISP=(OLD,KEEP),DCB=(DEN=1,RECFM=F,BLKSIZE=8192)
//GO.FT04F003 DD UNIT=2400,VOL=SER=NPS274,LABEL=(3,SL),DSNAME=JONZ96,
//               DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT02F004 DD UNIT=2400-1,VOL=SER=JONZ76,LABEL=(4,NL),
//               DISP=(OLD,KEEP),DCB=(DEN=1,RECFM=F,BLKSIZE=8192)
//GO.FT04F004 DD UNIT=2400,VOL=SER=NPS274,LABEL=(4,SL),DSNAME=JONZ96,
//               DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT02F005 DD UNIT=2400-1,VOL=SER=JONZ76,LABEL=(5,NL),
//               DISP=(OLD,KEEP),DCB=(DEN=1,RECFM=F,BLKSIZE=8192)
//GO.FT04F005 DD UNIT=2400,VOL=SER=NPS274,LABEL=(5,SL),DSNAME=JONZ96,
//               DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
```

```
INSERT SLASH STAR CARD HERE

III    FTOR
THE FTOR PROGRAM USES TAPE NPS274 CALLED JONZ96 AS AN INPUT AND TAPE NPS249
CALLED COEF AS AN OUTPUT.  FIVE FILES WERE PROCESSED.  INPUT TAPE IS ON LOGICAL
UNIT 8 AND OUTPUT TAPE IS ON LOGICAL UNIT 3.

//JONZ0089 JOB (0070,0353FP,OP94),'ROBT D JONES BOX J'
//    EXEC FORTCLG,REGION.GO=175K,TIME.GO=39
//FORT.SYSIN DD *

INSERT FTOR DECK HERE

//GO.FT08F001 DD UNIT=2400,VOL=SER=NPS274,DISP=OLD,LABEL=(1,SL),
//         DSN=JONZ96,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT08F002 DD UNIT=2400,VOL=SER=NPS274,DISP=OLD,LABEL=(2,SL),
//         DSN=JONZ96,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT08F003 DD UNIT=2400,VOL=SER=NPS274,DISP=OLD,LABEL=(3,SL),
//         DSN=JONZ96,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT08F004 DD UNIT=2400,VOL=SER=NPS274,DISP=OLD,LABEL=(4,SL),
//         DSN=JONZ96,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT08F005 DD UNIT=2400,VOL=SER=NPS274,DISP=OLD,LABEL=(5,SL),
//         DSN=JONZ96,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT03F001 DD UNIT=2400,VOL=SER=NPS249,DISP=(NEW,KEEP),LABEL=(1,SL),
//         DSN=COEF,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT03F002 DD UNIT=2400,VOL=SER=NPS249,DISP=(NEW,KEEP),LABEL=(2,SL),
//         DSN=COEF,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT03F003 DD UNIT=2400,VOL=SER=NPS249,DISP=(NEW,KEEP),LABEL=(3,SL),
//         DSN=COEF,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT03F004 DD UNIT=2400,VOL=SER=NPS249,DISP=(NEW,KEEP),LABEL=(4,SL),
//         DSN=COEF,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT03F005 DD UNIT=2400,VOL=SER=NPS249,DISP=(NEW,KEEP),LABEL=(5,SL),
//         DSN=COEF,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.SYSIN DD *
      70      2           0          1         8          0          4000.
   39        11          +1          1       000         -1
    2         0           0
    1             .02               U' CH.4 SAMP RATE 4KHZ   1KHZ FILT    M/SEC**2
    2             .02               E' CH.7 SAMP RATE 4KHZ   2KHZ FILT    DEG/SEC
      70      2           0          2         8          0          4000.
   40        11          +1          2       000         -1
    2         0           0
    1             .02               U' CH.4 SAMP RATE 4KHZ   100HZ FILT   M/SEC**2
    2             .02               E' CH.7 SAMP RATE 4KHZ   200HZ FILT   DEG/SEC
      70      2           0          3         8          0          4000.
  541        11          +1          3       000         -1
    2         0           0
```

```
  1              .02                U' CH.4 SAMP RATE 4KHZ   2KHZ FILT    M/SEC**2
  2              .02                E' CH.7 SAMP RATE 4KHZ   2KHZ FILT    DEG/SEC
     70     2              0         4        8         0             4000.
541        11             +1         4       000       -1
  2         0              0
  1              .02                U' CH.4 SAMP RATE 4KHZ   1KHZ FILT    M/SEC**2
  2              .02                E' CH.7 SAMP RATE 4KHZ   1KHZ FILT    DEG/SEC
     70     2              0         5        8         0             4000.
541        11             +1         5       000       -1
  2         0              0
  1              .02                U' CH.4 SAMP RATE 4KHZ  500HZ FILT    M/SEC**2
  2              .02                E' CH.7 SAMP RATE 4KHZ  500HZ FILT    DEG/SEC
BLANK CARD
ORANGE SLASH STAR CARD HERE
```

```
IV   SCOR
THE SCOR PROGRAM USED TAPE NPS249 CALLED COEF AS AN INPUT.  THE INPUT TAPE IS
MOUNTED ON LOGICAL UNIT 3.  IN THIS PARTICULAR RUN ONLY SPECTRA OF CHANNELS
ONE AND TWO WERE CALLED FOR; NO CROSS SPECTRA WERE SPECIFIED.  THE SEQUENCE
OF 1 1 2 AND 2 2 WILL GIVE SPECTRA AND CROSS SPECTRA (SEE KCHAN CARDS IN COMMENT
SECTION OF THE PROGRAM).  THE SPECTRA HAVE A BANDWIDTH OF 25 HERTZ AND A CENTER
FREQ. OF 5.0 HZ.

//JCNZ0070 JOB (0070,0353FP,OP94),'ROBT D JONES BOX J'
//     EXEC FORTCLGP,REGION.FORT=120K,REGION.GO=175K,TIME.GO=10
//FORT.SYSIN DD *

INSERT SCOR DECK HERE OR INSERT THE FOLLOWING CARD TO CALL PROGRAM FROM TAPE
NPS216, FILE 2 AND DELETE '//FORT.SYSIN DD *' CARD.

//FORT.SYSIN DD UNIT=2400,VOL=SER=NPS216,DISP=OLD,LABEL=(2,SL),
//          DSN=UBCSCOR

//GO.FT03F001 DD UNIT=2400,VOL=SER=NPS249,DISP=(OLD,KEEP),LABEL=(1,SL),
//          DSN=COEF,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT03F002 DD UNIT=2400,VOL=SER=NPS249,DISP=(OLD,KEEP),LABEL=(2,SL),
//          DSN=COEF,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT03F003 DD UNIT=2400,VOL=SER=NPS249,DISP=(OLD,KEEP),LABEL=(3,SL),
//          DSN=COEF,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT03F004 DD UNIT=2400,VOL=SER=NPS249,DISP=(OLD,KEEP),LABEL=(4,SL),
//          DSN=COEF,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.FT03F005 DD UNIT=2400,VOL=SER=NPS249,DISP=(OLD,KEEP),LABEL=(5,SL),
//          DSN=COEF,DCB=(DEN=2,RECFM=VS,BLKSIZE=8204)
//GO.SYSIN DD *
...POWER SPECTRUM PLOT OF TAPE 203(1)   ROBERT D JONES..OCEANOGRAPHY....
     70       2         275          1          1          13         0
    8.0       1.0        8.0         1.0        0.0        .5        8.0
```

```
  0          5.0         25.0     0
  1           1
  2           2
     70       2           213               1         2         13         0
     8.0          1.0          8.0              1.0       0.0         .5         8.0
  0          5.0         25.0     0
  1           1
  2           2
     70       2           138               1         3         13         0
     8.0          1.0          8.0              1.0       0.          .5         8.0
  0          5.0         25.0     0
  1           1
  2           2
     70       2           137               1         4         13         0
     8.0          1.0          8.0              1.0       0.          .5         8.0
  0          5.0         25.0     0
  1           1
  2           2
     70       2            68               1         5         13         0
     8.0          1.0          8.0              1.0       0.          .5         8.0
  0          5.0         25.0     0
  1           1
  2           2
BLANK CARD HERE
ORANGE SLASH STAR CARD HERE


V   FCPLOT
THE FCPLOT PROGRAM MAY BE USED IN PLACE OF SCOR OR IN ADDITION TO SCOR. THE
INPUT TAPE NPS249 IS MOUNTED ON LOGICAL UNIT 9 AND 5 FILES ARE PROCESSED.  THE
OUTPUT IS A POWER SPECTUM AND AN AMPLITUDE VS FOURIER COEFFICIENTS DRAWING.
VARIOUS OTHER OUTPUT ARE AVAILABLE.

//JCNZ0101 JOB (0070,0353FP,OP94),'ROBT D JONES BOX J'
//   EXEC FORTCLGP,REGION.GO=150K,TIME.GO=10

//FORT.SYSIN DD UNIT=2400,VOL=SER=NPS216,DISP=OLD,LABEL=(3,SL),
//       DSN=UBCFCPLT
THIS CARD CALLS FCPLOT FROM NPS216FILE3.  BY USING ONLY A '//FORT.SYSIN DD *'
CARD THE DECK OF FCPLOT PROGRAM MAY BE USED.

//GO.FT09F001 DD UNIT=2400,VOL=SER=NPS249,DISP=OLD,LABEL=(1,SL),
//   DSN=COEF
//GO.FT09F002 DD UNIT=2400,VOL=SER=NPS249,DISP=OLD,LABEL=(2,SL),
//   DSN=COEF
//GO.FT09F003 DD UNIT=2400,VOL=SER=NPS249,DISP=OLD,LABEL=(3,SL),
//   DSN=COEF
//GO.FT09F004 DD UNIT=2400,VOL=SER=NPS249,DISP=OLD,LABEL=(4,SL),
```

```
//    DSN=COEF
//GO.FT09F005 DD UNIT=2400,VOL=SER=NPS249,DISP=OLD,LABEL=(5,SL),
//    DSN=COEF
//GO.SYSIN DD *
......PLOT OF FOURIER COEFFICIENTS OF TAPE 203...NPS249(1-5) R.D.JONES..
     1     1     1  275     1     1     0     0     0     1
......PLOT OF FOURIER COEFFICIENTS OF TAPE 203...NPS249(1)CH.1 R.D.JONES
           8         10       000.0         1.0           8        1.0
     2     1     1  213     1     1     0     0     0     1
......PLOT OF FOURIER COEFFICIENTS OF TAPE 203...NPS249(2)CH.1 R.D.JONES
           8         10       000.0         1.0           8        1.0
     3     1     1  138     1     1     0     0     0     1
......PLOT OF FOURIER COEFFICIENTS OF TAPE 203...NPS249(3)CH.1 R.D.JONES
           8         10       000.0         1.0           8        1.0
     4     1     1  137     1     1     0     0     0     1
......PLOT OF FOURIER COEFFICIENTS OF TAPE 203...NPS249(4)CH.1 R.D.JONES
             8          10       000.0         1.0           8        1.0
     5     1     1   68     1     1     0     0     0     1
......PLOT OF FOURIER COEFFICIENTS OF TAPE 203...NPS249(5)CH.1 R.D.JONES
           8         10       000.0         1.0           8        1.0
BLANK CARD
ORANGE SLASH STAR CARD HERE
```

```
THIS PROGRAM IS TO DIGITIZE ANALOG DATA ON THE HYBRID
SYSTEM UTILIZING UP TO SIX CHANNELS FOR THE DIGITIZED DATA.

THE TYPED IN OPTIONS  ARE, 1...NEW PARAMETERS
                           2...START
                           3...END FILE
                           4...REWIND
                           5...SKIP FILES
                           6...LIST DIGITIZED DATA
                           7...DIGITAL TO ANALOG CONVERSION

THE INPUT PARAMETERS ARE, NREC, NSAMP, NCHAN, ITAPE.

NREC=MAX. NO. OF RECORDS TO BE DIGITIZED IN THE FILE
NSAMP=NO. OF WORDS IN ONE BLOCK / NCHAN
NCHAN=NO. OF CHANNELS DIGITIZED
ITAPE=NO. OF TAPE DRIVE UNIT USING

                    ROBERT LIMES   1970

¬JOB
¬FORTRAN LS,GO
      DIMENSION IBUF(2048,2), LOCB(-1'1), MAXBS(-1'1)
      INTEGER RECNUM
      NAMELIST NREC, NSAMP, NCHAN, ITAPE,NDEL
 1    INPUT(101)
      LOCB(-1)=LOCF(IBUF(1,1))
      LOCB(1)=LOCF(IBUF(1,2))
      NWORDS=NSAMP*NCHAN
      MAXBS(-1)=LOCB(-1)+NWORDS-1
      MAXBS(1)=LOCB( 1)+NWORDS-1
      IF(SENSE SWITCH 6)2,15
 2    NB=1
      IND=0
      RECNUM=0
      NEWBUF=LOCB(1)
      MAXB=MAXBS(-1)
      CALL ADSTART(NCHAN,LOCB(-1),NEWBUF,MAXB,RECNUM,11S)
      MAXB=MAXBS(1)
 3    IF(TEST(1).GT.0)GO TO 3
      CALL ENABLE
 5    CONTINUE
 10   GO TO 5
 11   IF(IND.EQ.1)GO TO 90
      IF(TEST(1).GT.0.OR.RECNUM.GE.NREC)CALL DISABLE
      NB=-NB
      NEWBUF=LOCB(NB)
      MAXB=MAXBS(NB)
      IND=1
      CALL BUFFEROUT(ITAPE,1,IBUF(1,(3+NB)/2),NWORDS,IND)
      IF(TEST(1).LT.0.AND.RECNUM.LT.NREC)GO TO 5
      CALL ADSTOP
X     CALL PROCESS(IBUF,NSAMP,NCHAN,2S)
      OUTPUT(101)RECNUM
 15   OUTPUT(101)-OPTION=(I1)-
      READ(101,100)NOPT
 100  FORMAT(I1)
      GO TO(1,2,30,40,50,60,70)NOPT
 30   ENDFILE(ITAPE)
      OUTPUT(101)-EOF-
      GO TO 15
 40   REWIND(ITAPE)
      GO TO 15
 50   OUTPUT(101)-SKIPFILES=(I4)-
      READ(101,101)NF
 101  FORMAT(I4)
      DO 55 I=1,NF
 51   CALL BUFFERIN(ITAPE,1,IBUF(1,1),1,IND)
 52   IF(IND.LT.2)GO TO 52
```

```
      IF(IND.NE.3)GO TO 51
55    CONTINUE
      OUTPUT(101)NF
      GO TO 15
60    OUTPUT(101)-NUMWORDS TO LIST=(I4)-
      READ(101,101)NW
      WRITE(101,105)NW,NCHAN
105   FORMAT(- WRITE - I4 - WORDS, - I2 - AT A TIME-)
      IND=1
      CALL BUFFERIN(ITAPE,1,IBUF(1,1),NWORDS,IND)
66    IF(IND.EQ.1)GO TO 66
62    GO TO(62,63,64,65)IND
63     WRITE(6,102)
102   FORMAT(1H1)
      DO 631 I=1,NW,NCHAN
      WRITE(6,104)(IBUF(J,1),J=I,I+NCHAN-1)
104    FORMAT(12O10)
631   CONTINUE
      GO TO 15
64     OUTPUT(101)-EOF READ-
      GO TO 15
65     OUTPUT(101)-READ ERR-
      GO TO 63
70    OUTPUT(101)-START ANALOG RECORDER-
      OUTPUT(101)-TYPE * C/R TO CONTINUE-
      INPUT(101)
      IND=1
      CALL BUFFERIN(ITAPE,1,IBUF,NWORDS,IND)
76    IF(IND.EQ.1)GO TO 76
71    GO TO(71,72,64,74)IND
72    DO 73 I=1,NWORDS
73    IBUF(I,1)=IBUF(I,1)/2**10
      DO 75 I=1,NWORDS,NCHAN
      DO 75 J=1,NCHAN
      CALL DAC(J,IBUF(I+J-1,1))
      N=NDEL
      CALL DELAY
75    CONTINUE
      GO TO 15
74    OUTPUT(101)-READ ERROR-
      GO TO 72
90    CALL DISABLE
      CALL ADSTOP
      OUTPUT(101)-RATE ERR-,RECNUM
      GO TO 15
      END


      SUBROUTINE PROCESS(IB,NS,NC,IS)
      DIMENSION IB(NC,NS),MEAN(10),SIGMA(10)
      REAL MEAN
      SCALE=100./2**23
      DO 1 I=1,10
1     SIGMA(I)=MEAN(I)=0.
      DO 100 I=1,NC
      DO 10 J=1,NS
10    MEAN(I)=MEAN(I)+SCALE*IB(I,J)
      MEAN(I)=MEAN(I)/NS
      DO 20 J=1,NS
20    SIGMA(I)=SIGMA(I)+(MEAN(I)-IB(I,J)*SCALE)**2
      SIGMA(I)=SQRT(SIGMA(I)/NS)
      WRITE(6,1000)I,MEAN(I),SIGMA(I)
1000  FORMAT($ CHAN $I2$  MEAN=$F8.4$  SIGMA=$F8.4/)
100   CONTINUE
30    IF(TEST(1).LT.0)GO TO 30
      IF(TEST(2).GT.0)RETURN
      RETURN IS
      END
¬META9300 SI,LO,GO
$ADSTART PZE
        BRM     9SETUPN
        PZE     6
```

```
NCH     PZE
BUF     PZE
NEWBUF  PZE
MAXB    PZE
RECNUM  PZE
NEXLOC  PZE
        LDA     ENDBRM
        XMA     040
        STA     SV040
        LDA     INTBRM
        XMA     052
        STA     SV052
        LDA     *NCH
        STA     INCR
        ADD     =COMM
        COPY    (5,1)
        STA     COMLOC
        LDA     *NCH
        LLSA    15
        ADD     =COMM
        STA     0,1
        STA     CONTR
        LDA     *BUF
        STA     COMM
       LDA     *MAXB
       STA     MAX
        SKR     NFULL
        BRU     $-1
        EOM     034001
        POT     CONTR
        BRR     ADSTART
INTBRM  BRM     ADFAST
ENDBRM  BRM     ENDAD
SV040   PZE
ENDAD   PZE
        DIR
        HLT
        EOM     034001
        POT     CONTR
        EIR
        BRC     *ENDAD
$ADSTOP  PZE
        LDA     SV040
        STA     040
        LDA     SV052
        STA     052
        STZ     *COMLOC
        MPO     ADSTOP
        BRR     ADSTOP
COMLOC  PZE
$ADFAST  PZE
        DIR
        STD     SVAB
        SKN     NFULL
        BRU     NXTBUF
        LDP     INCR
        ADD     COMM
        STA     COMM
        ADD     INCR
       SKL     MAX
        STB     NFULL
        LDP     SVAB
        EIR
        BRC     *ADFAST
NXTBUF  LDA     *NEWBUF
        STA     COMM
        LDA     *MAXB
        STA     MAX
        SKR     NFULL
        BRU     $-1
        MPO     *RECNUM
        LDP     SVAB
```

```
        EIR
        BRC       *NEXLOC
COMM    RES       33
CCNTR   PZE
MAX     PZE
SVAB    RES       2
INCR    DATA      6,0
NFULL   PZE
SV052   PZE
        END
¬EOF
¬LOAD XR,MAP
```

THIS PROGRAM WILL OBTAIN A LISTING OF ONE OF THE THREE UBC TIME SERIES PROGRAMS ON FILE AT THE NAVY POSTGRADUATE SCHOOL, MONTEREY,CA.
THE EXPAMPLE PROGRAM IS WRITTEN TO OBTAIN UBCFTOR PROGRAM LISTING, TAPE NPS216, FILE 1.

UBC TIME SERIES PROGRAMS LISTING GENERATION

ROBERT D. JONES NPGS MAR 1971

```
//  (STANDARD GREEN JOB CARD)
// EXEC PGM=IEBPTPCH
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=2400,LABEL=(1,SL),VOL=SER=NPS216,DISP=OLD,
//        DCB=(RECFM=FB,LRECL=80,BLKSIZE=1600),DSNAME=UBCFTOR
//SYSUT2 DD SYSOUT=A
//SYSIN DD *,DCB=BLKSIZE=80
          PRINT MAX FLDS=1
          RECORD FIELD=(80)
INSERT SLASH STAR CARD HERE
```

THIS PROGRAM REQUIRES 58K BYTES OF STORAGE AND 1.6 SECONDS OF COMPUTER TIME.
TO OBTAIN OTHER LISTINGS OF THE UBC SERIES CHANGE THE 'LABEL' PARAMETER AND 'DSNAME' PARAMETER.
UBCSCOR PROGRAM: CHANGE TO LABEL=(2,SL) AND DSNAME=UBCSCOR
UBCFCPLT PROGRAM: CHANGE TO LABEL=(3,SL) AND DSNAME=UBCFCPLT

THIS PROGRAM WILL OBTAIN A SOURCE DECK FOR ANY ONE OF THREE UBC TIME SERIES PROGRAMS ON FILE AT THE NAVY POSTGRADUATE SCHOOL, MONTEREY,CA.

THE EXAMPLE PROGRAM IS WRITTEN TO OBTAIN UBCFTOR SOURCE DECK ON TAPE 216, FILE 1.

UBC TIME SERIES PROGRAMS SOURCE DECK GENERATION

ROBERT D. JONES NPGS MAR.,1971

```
//(STANDARD GREEN JOB CARD)
// EXEC PGM=IEBPTPCH
//SYSPRINT DD DSYSOUT=A
//SYSUT1 DD UNIT=2400,LABEL=(1,SL),VOL=SER=NPS216,DISP=OLD,
//        DCB=(RECFM=FB,LRECL=80,BLKSIZE=1600),DSNAME=UBCFTOR
//SYSUT2 DD SYSOUT=B
//SYSIN DD *
       PUNCH
INSERT SLASH STAR CARD HERE.
```

THIS PROGRAM REQUIRES 58K BYTES OF STORAGE AND 1.6 SECONDS OF COMPUTER TIME.
TO OBTAIN ANOTHER SOURCE DECK CHANGE 'LABEL' AND 'DSNAME' TO THE DESIRED PROGRAM BELOW.
UBCSCOR PROGRAM: CHANGE TO LABEL=(2,SL) AND DSNAME=UBCSCOR
UBCFCPLT PROGRAM: CHANGE TO LABEL=(3,SL) AND DSNAME=UBCFCPLT

```
// ( STANDARD GREEN JOB CARD )

THE FOLLOWING TWO CARDS ARE EXAMPLE CONTROL CARDS.
//CONVERT EXEC FORTCALG,REGION.GO=100K,TIME.GO=10
//FORT.SYSIN DD *


                    CONVERSION PROGRAM FOR UBC TAPE SERIES


THIS PROGRAM IS TO CONVERT A SEVEN TRACK TAPE TO A NINE
TRACK TAPE  FOR USE ON THE IBM 360/67 OS.  THE SEVEN TRACK
IS DERIVED FROM THE SDS 9300/CI 5000 HYBRID COMPUTER SYSTEM
AT THE NAVY POSTGRADUATE SCHOOL, MONTEREY,CA.  THE OUTPUT
TAPE IS TO BE USED AS INPUT TO THE UBCFTOR PROGRAM, ON TAPE
216, FILE 1.

THE INPUT TAPE IS ON LOGICAL UNIT 2 AND THE OUTPUT TAPE IS
LOGICAL UNIT 4.  THE EXAMPLE INPUT TAPE IS'JONZ76' AND THE
EXAMPLE OUTPUT TAPE IS NPS274.  ENSURE THE JCL CARDS REFLECT
THE PROPER TAPE PARAMETERS IN THE DCB SECTION.

                                        ROBERT D. JONES, MAR.1971


DIMENSION INDATA AND DATA TO FIT THE MAXIMUM  NUMBER OF
WORDS IN ANY ONE BLOCK.
      DIMENSION INDATA(2048),DATA(2048)
      REWIND 2
      REWIND 4
      IEND=0
SET NCHAN AND KMAX TO THE DESIRED NUMBER OF CHANNELS AND
THE MAXIMUM NUMBER OF WORDS IN THE BLOCK OF DATA ONE
WISHES TO READ.  NCHAN AND KMAX MUST BE CONSTANT FOR THE
ENTIRE TAPE.  IF DIFFERENT VALUES MUST BE USED, RE-ENTER
THE VALUES AND RUN THE PROGRAM AGAIN ADJUSTING THE JCL
CARDS TO IDENTIFY THE FILES DESIRED ON THE TAPE.
      NCHAN=2
      KMAX=2048
      J=0
ONE BLOCK OF DATA IS NOW BEING READ.
  31  READ(2,3,END=40,ERR=50)INDATA
SET FORMAT TO COVER ALL WORDS IN ONE BLOCK OF DATA.
    3 FORMAT(32(64A4))
      J=J+1
THE FORM SUBROUTINE CONVERTS THE BLOCK TO 9 TRACK FORM.
      CALL FORM (INDATA)
      IF(J.LE.1)WRITE(6,70)J
   70 FORMAT('1',10X,'RECORD NO.=',I5)
      IF(J.GT.1)WRITE(6,71)J
  71  FORMAT(' ',10X,'RECORD NO.=',I5)
SET DO LOOP TO THE MAXIMUM NUMBER OF WORDS IN THE BLOCK.
      DO 1 I=1,2048
    1 DATA(I)=INDATA(I)
SET I TO THE MAXIMUM NUMBER OF WORDS IN THE BLOCK.
      IF(J.LE.1)WRITE(6,66)(DATA(I),I=1,2048)
   66 FORMAT(1X,8E16.8)
      WRITE(4)KMAX,NCHAN,DATA
      GO TO 31
   50 WRITE(6,51)J
   51 FORMAT('0',5X,'READ ERROR,RECORD NO.=',I5)
      GO TO 31
   40 WRITE(6,41) J
   41 FORMAT('0',5X,'END OF FILE, RECORD NO.=',I5)
      END FILE 4
A FILE IS FINISHED AND THE NEXT FILE IS LOOKED FOR BY THE
SUBSEQUENT 'IF' BRANCH.
      IEND=IEND + 1
THE IF BRANCH MUST BE SET TO THE MAXIMUM NUMBER OF FILES
PROCESSED IN THE PROGRAM RUN.  EXAMPLE: FILES 1,3,5 ARE
```

```
PROCESSED IN ONE PROGRAM RUN OF THE SEVEN TRACK TAPE.  SET
THE IF BRANCH TO THREE.
      IF(IEND.LT.5)J=0
      IF(IEND.LT.5)GO TO 31
      REWIND 4
NOW, READ AND PRINT THE LAST BLOCK OF DATA ON THE LAST FILE
REQUESTED.
      READ(4,81)DATA
SET FORMAT SIZE TO THE BLOCK SIZE.
   81 FORMAT(32(64A4))
SET I TO THE NUMBER OF WORDS IN THE BLOCK.
      WRITE(6,82)(DATA(I),I=1,2048)
  82  FORMAT(1X,8E16.8)
      STOP
      END
INSERT SLASH STAR CARD HERE

ASSEMBLER LANGUAGE PROGRAM STARTS HERE.
INSERT ASSEMBLER PROGRAM IMMEDIATELY AFTER THE /* CARD.

//ASM.SYSIN DD *



SUBROUTINE FORM(INDATA)

THIS SUBROUTINE WILL CONVERT 24-BIT BINARY WORDS STORED IN
INDATA TO 32-BIT WORDS AND PUT THESE SAME WORDS BACK
INTO INDATA.

FORM        START 0
            STM 14,12,12(13)
            BALR 6,0
            USING *,6
            USING DATA,7
            SR  7,7
            L    11,=F'1024'
            L   12,0(1)
LOOP        L   2,NUM(12)
            LR   3,7
            SRDL 2,6
            SRL 2,2
            SRDL  2,6
            SRL   2,2
            SRDL  2,6
            SRL   2,2
            SRDL  2,6
            ST  3,NUM(12)
            LA   12,4(12)
            BCT  11,LOOP
            LM 2,12,28(13)
            MVI  12(13),X'FF'
            BCR  15,14
DATA        DSECT
NUM         DS   1F
            END
INSERT SLASH STAR CARD HERE

EXAMPLES OF JOB CONTROL LANGUAGE CARDS FOR FIVE FILES ON A
TAPE ARE LISTED.  CHANGES WILL HAVE TO BE MADE TO THE CARDS
BUT THE FORMAT IS CORRECT.

THIS JCL CARD IS FOR ADDITIONAL PRINTER SPACE.
//GO.FT06F001 DD SPACE=(CYL,(6,1))

THE FOLLOWING TWO JCL CARDS IDENTIFY THE READ TAPE,FILE 1.
//GO.FT02F001 DD UNIT=2400-1,VOL=SER=JONZ76,LABEL=(1,NL),
//                DISP=(OLD,KEEP),DCB=(DEN=1,RECFM=F,BLKSIZE=81

THE FOLLOWING TWO JCL CARDS IDENTIFY THE WRITE TAPE,FILE 1.
//GO.FT04F001 DD UNIT=2400,VOL=SER=NPS274,LABEL=(,SL),DSNAME
```

```
//                 DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=VS,BLKSIZE=8

ETC., ETC., UNTIL FIVE SETS OF JCL CARDS ARE INSERTED.
RECALL THAT FIVE FILES PERTAINS ONLY TO THIS EXAMPLE.
//GO.FT02F002 DD UNIT=2400-1,VOL=SER=JONZ76,LABEL=(2,NL),
//                 DISP=(OLD,KEEP),DCB=(DEN=1,RECFM=F,BLKSIZE=81
//GO.FT04F002 DD UNIT=2400,VOL=SER=NPS274,LABEL=(2,SL),DSNAM
//                 DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=VS,BLKSIZE=8
//GO.FT02F003 DD UNIT=2400-1,VOL=SER=JONZ76,LABEL=(3,NL),
//                 DISP=(OLD,KEEP),DCB=(DEN=1,RECFM=F,BLKSIZE=81
//GO.FT04F003 DD UNIT=2400,VOL=SER=NPS274,LABEL=(3,SL),DSNAM
//                 DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=VS,BLKSIZE=8
//GO.FT02F004 DD UNIT=2400-1,VOL=SER=JONZ76,LABEL=(4,NL),
//                 DISP=(OLD,KEEP),DCB=(DEN=1,RECFM=F,BLKSIZE=81
//GO.FT04F004 DD UNIT=2400,VOL=SER=NPS274,LABEL=(4,SL),DSNAM
//                 DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=VS,BLKSIZE=8
//GO.FT02F005 DD UNIT=2400-1,VOL=SER=JONZ76,LABEL=(5,NL),
//                 DISP=(OLD,KEEP),DCB=(DEN=1,RECFM=F,BLKSIZE=81
//GO.FT04F005 DD UNIT=2400,VOL=SER=NPS274,LABEL=(5,SL),DSNAM
//                 DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=VS,BLKSIZE=8

ONE MAY HAVE AS MANY FILES AS DESIRED. IF THE TAPE IS FILLED
CONSULT THE THESIS SECTION ON MULTI-DATA SETS AND MULTI-
VOLUME MANIPULATION.

REMOVE COMMENT CARDS FROM JCL DECK BEFORE UTILIZING PROGRAM.
```

BIBLIOGRAPHY

1. Blackman, R. B. and Tukey, J. W., The Measurement of Power Spectra, Dover Press, 1959.

2. Boston, N. E. J., An Investigation of High Wave Number Temperature and Velocity Spectra in Air, Ph.D. Thesis, University of British Columbia, Vancouver, 1970.

3. Cochran, W. T. and others, "What is the Fast Fourier Transform?", IIEE Transactions on Audio and Electroacoustics, Au-15 (2), p. 45-55, 1967.

4. Cooley, J. W. and Tukey, J. W., "An Algorithm for the Machine Calculation of Complex Fourier Series", Mathematics of Computations, 19 (90), p. 297-301, 1965.

6. Naval Postgraduate School Computer Facility Technical Note 0211-04, Conversion Procedures for Electrical Engineering Computer Laboratory Tapes and Fleet Numerical Weather Central Tapes, by P. C. Zeleny and R. D. Brunell, April 1969.

7. Wilson, J. R., Boston, N. E. J., Denner, W. W., "Digital Analysis of Turbulence Data on the IBM 360/67 at the Naval Postgraduate School", NPS-58DW 9071A, 1969.

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13. ABSTRACT

Time series data consisting of temperature and velocity fluctuations recorded two to four meters above a tidal mud flat were processed to produce power spectra. The analog data were first processed through an Analog-to-Digital computer consisting of a Hybrid Computer System (XDS 9300/Ci 5000). The resulting tapes, in octal representation, were converted to hexadecimal representation for further processing on a 768k byte storage digital computer (IBM 360/67). A series of three digital programs were used to compute and plot Fourier coefficients in spectral form. Digital data processing procedures using magnetic tape on the two computer systems is explained in detail and specific examples of programs and control card decks are given. Significant noise levels were encountered in the Hybrid Computer System (ADC) which must be eliminated in future studies.

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Digital Data Processing						
Fast-Fourier transform						
Power spectra						
Correlation Analysis						
Phase analysis						
Spectra plotting						
Cross spectra plotting						
Time series analysis						

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c.1 Time series analysis of analog data by analog-to-digital and digital data processing methods at the Naval Postgraduate School.